PB86-135407

Investigation of Parasites in Sludges and Disinfection Techniques

Tulane Univ., New Orleans, LA

Prepared for

Health Effects Research Lab.
Research Triangle Park, NC

Nov 85

U.S. Department of Commerce
National Technical Information Service
NTIS

PB86-135407

EPA/600/1-85/022
November 1985

INVESTIGATION OF PARASITES IN SLUDGES AND DISINFECTION TECHNIQUES

R.S. Reimers, M.D. Little, A.J. Englande, Jr.,
D.B. McDonell, D.D. Bowman, and J.M. Hughes
School of Public Health and Tropical Medicine
Tulane University
New Orleans, Louisiana 70112

Cooperative Agreement No. CR-806711-01

Project Officer

Norman E. Kowal
Toxicology and Microbiology Division
Health Effects Research Laboratory
Cincinnati, Ohio 45268

This study was conducted in cooperation with the
Water Engineering Research Laboratory
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

HEALTH EFFECTS RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NORTH CAROLINA 27711

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

NOTICE

The information in this document has been funded wholly or in part by the Water Engineering Research Laboratory and the Health Effects Research Laboratory, United States Environmental Protection Agency under assistance agreement #CR-806711 to Tulane University. It has been subject to the Agency's review and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA/600/1-85/022

2.

3. RECIPIENT'S ACCESSION NO. PB86 135407/AS

4. TITLE AND SUBTITLE
INVESTIGATION OF PARASITES IN SLUDGES AND DISINFECTION TECHNIQUES

5. REPORT DATE November 1985

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S) R.S. Reimers M.D. Little, A.J. Englande, Jr., D.B. McDonell, D.D. Bowman, and J.M. Hughes

8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
School of Public Health and Tropical Medicine
Tulane University
New Orleans, LA 70112

10. PROGRAM ELEMENT NO. AAYB1B

11. CONTRACT/GRANT NO. CR 806711

12. SPONSORING AGENCY NAME AND ADDRESS
U.S. Environmental Protection Agency
Health Effects Research Laboratory, ORD
Research Triangle Park, NC 27711

13. TYPE OF REPORT AND PERIOD COVERED Final Aug. 1979 - May 1982

14. SPONSORING AGENCY CODE EPA 600/11

15. SUPPLEMENTARY NOTES
Project Officer, Norman E. Kowal Project Report/Summary

16. ABSTRACT

The objectives of this research grant were to: 1) assess the presence and densities of resistant stages of parasites in municipal wastewater sludges (sewage) in northern United States; 2) compare the results of this study with the results of our previous study of sludges in southern United States; 3) to evaluate several decontamination techniques for their effectiveness in inactivating parasites in waste sludges; and 4) develop a standard method for the parasitologic examination of waste sludges. Sludge samples from all phases of treatment (i.e., primary, etc.) were collected during the fall, winter and summer from 48 municipal wastewater treatment plants located in New York (13 plants), Ohio (12 plants), Minnesota (11 plants), and Washington (12 plants).

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT Release to Public

19. SECURITY CLASS *(This Report)* unclassified

20. SECURITY CLASS *(This page)* unclassified

21. NO. OF PAGES 253

22. PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

FOREWORD

The many benefits of our modern, developing, industrial society are accompanied by certain hazards. Careful assessment of the relative risk of existing and new man-made environmental hazards is necessary for the establishment of sound regulatory policy. These regulations serve to enhance the quality of our environment in order to promote the public health and welfare and the productive capacity of our Nation's population.

The complexities of environmental problems originate in the deep interdependent relationships between the various physical and biological segments of man's natural and social world. Solutions to these environmental problems require an integrated program of research and development using input from a number of disciplines. The Health Effects Research Laboratory, Research Triangle Park, NC and Cincinnati, OH, conducts a coordinated environmental health research program in toxicology, epidemiology, and clinical studies using human volunteer subjects. Wide ranges of pollutants known or suspected to cause health problems are studied. The research focuses on air pollutants, water pollutants, toxic substances, hazardous wastes, pesticides, and non-ionizing radiation. The laboratory participates in the development and revision of air and water quality criteria and health assessment documents on pollutants for which regulatory actions are being considered. Direct support to the regulatory function of the Agency is provided in the form of expert testimony and preparation of affidavits as well as expert advice to the Administrator to assure the adequacy of environmental regulatory decisions involving the protection of the health and welfare of all U.S. inhabitants.

Research and development is that necessary first step in problem solution, and it involves defining the problem, measuring its impact, and searching for solutions. The Water Engineering Research Laboratory develops new and improved technology and systems for the prevention, treatment and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

This research grant has measured parasite densities and occurrences in northern sewage sludges. From laboratory and field studies, the following processes have shown effect in parasite inactivation: drying beds, ammonification, thermophilic digestion, aerobic digestion, liming of aerobically digested sludges, and ultrsonication of municipal sludges. In addition, data on parasites from both the northern and southern United States were also compared.

F. Gordon Hueter, Ph.D.
Director
Health Effects Research Laboratory

ABSTRACT

The objectives of this research grant were to: 1) assess the presence and densitied of resistant stages of parasites in municipal wastewater sludges (sewage) in northern United states, (2) compare the results from our previous southern study to evaluate several decontamination techniques for their effectiveness in inactivating parasites in waste sludges, and (3) develop a standard method for the parasitologic examination of waste sludges. Sludge samples from all phases of treatment (i.e., primary, etc.) were collected during the fall, winter and summer from 48 municiapl wastewater treatment plants located in New York (13 plants), Minnesota (11 plants) and Washington (12 plants). Resistant stages of twenty types of parasites were found in these samples which may represent 25 to 30 different human and animal parasites. The most commonly occurring parasites in the northern sludges were the eggs of Ascaris spp. (roundworms of humans and pigs), *Trichuris trichiura* (whipworm of humans), *Trichuris vulpis* whipworm of dogs), and *Toxocara* spp. (roundworms of dogs and cats). These parasites were also the most commonly found ones in southern sludges. Viable eggs of one or more of these four parasites were found in 82% of all samples of northern sludges. In general, the densities of these four parasites were higher in sludges in Washington and New York than they were in Ohio and Minnesota. Also, the densities of parasites in northern sludges were generally lower than they were found to be in sludges from southern states examined earlier. The presence of hog or meat processing wastes in raw waste did not significantly affect the densities of the eggs of *Ascaris* or other parasites in northern sludges. The densities of viable eggs of *Ascaris*, *T. trichiura*, *T. vulpis* and *Toxocara* in northern drying bed sludges decreased as the moisture content of the sludge decreased; however, the levels of moisture content observed did not appear to be low enough to be the primary cause of decreased viability even though the moisture content was found to be significant in the north. Factors such as age of sludge in the bed, type of digested sludge, temperature, climate, etc., probably also played a role. In laboratory studies, it was found that aerobic digestion at 35°C over a ten-day period inactivated *Ascaris* eggs by 30 to 50 percent. Mesophilic aerobic digestion was also noted to enhance inactivation by caustic stabilization or ammonification. Dosages of 1,000 mg or more of lime per gram of dry sludge solids completely inactivated *Ascaris* eggs in aerobically digested sludge within ten days at ambient temperatures. In caustic stabilization experiments, a hydroxide concentration of 10^{-1} molar (ph 13) did not inactivate *Ascaris* eggs in sludges that had been aerobically digested at 25°C, but did inactivated eggs in sludges digested at 35°C. The addition of ammonium sulfate to caustic-stabilized, 25°C aerobically digested sludges killed all *Ascaris* eggs within ten days when the ammonia concentration was 0.5 percent or greater by weight. When ammonia gas was used, a concentration of one percent ammonia by weight completely killed *Ascaris* eggs within ten days. Ultrasonication with 600 watts and 33 kHz for one minute inactivated 50 percent of the *Ascaris* eggs in samples and an exposure time of 12 minutes killed 90 percent of the eggs. Irradiation with Cobalt 60 at 200 Krad or more caused complete inactivation of Ascaris eggs. A standard parsitologic method for examining waste sludge was developed.

This report was submitted in fulfillment of cooperative agreement #CR-806711 by Tulane University under the sponsorship of the U.S. Environmental Protection Agency. This report covers a period from August 1979 to May 1982 and work was completed as of December 1984.

CONTENTS

Foreword iii
Abstract iv
Figures viii
Tables xii
Acknowledgments xix

1. Introduction 1
2. Conclusions 2
3. Recommendations 5
4. Parasites in Sludge 7
    Wastewater Treatment Processes 15
5. Part I. Parasites in Sludges in the United States and Laboratory Evaluation of Disinfection Techniques 22
    Methodology 22
    Results 32
    Discussion 117
6. Part II. Development of a Standard Method for the Parasitological Examination of Sludge 139
    Parasitologic Method for Wastewater Sludges 139
    Parasitologic Method for Municipal Wastewater Sludges. 149

References 163
Appendices 166

A. Letter, Enclosure and Form for Field Studies 163
B. Data Record Forms, SIC Codes, and Key to Sampling Sites . . 166
C. Procedure for Parasitologic Examination of Waste Sludges . 175
D. Results of Field Studies 180
E. Geographic Regions in the South in Which Muncipal Waste Treatment Plants Were Studied 231
F. Results of Laboratory Studies on the Effects of Continuous Aerobic Digestion on *Ascaris* Eggs 232

FIGURES

Number **Page**

1. Average percent reduction of viable parasite eggs by unit process 14
2. Plot of log of number of viable *Ascaris* eggs in raw sludge grouped by moisture content of drying bed sludges 18
3. Viable *Ascaris* eggs in positive samples of undigested sludge vs. population served: northern states 47
4. Total *Ascaris* eggs (viable and nonviable) in positive samples of undigested sludge vs. population served: northern states 48
5. Viable *Trichuris trichiura* eggs in positive samples of undigested sludge vs. population served: northern states . . . 49
6. Total *Trichuris trichiura* eggs (viable and nonviable) in positive samples of undigested sludges vs. population served: northern states 50
7. Viable *Trichuris vulpis* eggs in positive samples of undigested sludge vs. population served: northern states . . . 51
8. Total *Trichuris vulpis* eggs (viable and nonviable) in positive samples of undigested sludge vs. population served: northern states 52
9. Viable *Toxocara* eggs in positive samples of undigested sludge vs. population served: northern states 53
10. Total *Toxocara* eggs (viable and nonviable) in positive samples of undigested sludge vs. population served: northern states 54
11. Viable *Trichuris trichiura* eggs in positive samples of undigested sludge vs. population served: southern states . . . 57
12. Total *Trichuris trichiura* eggs (viable and nonviable) in positive samples of undigested sludge: southern states . . . 58

Number Page

13. Viable Ascaris eggs in positive samples of digester sludge vs. population served by the treatment plant: northern states 68

14. Total Ascaris eggs (viable and nonviable) in positive samsamples of digester sludge vs. population served: northern states 69

15. Viable Trichuris trichiura eggs in positive samples of digester sludge vs. population served: northern states . . 70

16. Total Trichuris trichiura eggs (viable and nonviable) in positive samples of digester sludge vs. population served: northern states 71

17. Viable Trichuris vulpis eggs in positive samples of digested sludge vs. population served: northern states 72

18. Total Trichuris vulpis eggs (viable and nonviable) in positive samples of digester sludge vs. population served: northern states 73

19. Viable Toxocara eggs in positive samples of digester sludge vs. population served: northern states 74

20. Total Toxocara eggs (viable and nonviable) in positive samples of digester sludge vs. population served: northern states 75

21. Viable Ascaris eggs in positive samples of drying bed sludges vs. percent moisture content of that sludge: northern states 82

22. Viable Trichuris trichiura eggs in positive samples of drying bed sludges vs. percent moisture content of that sludge: northern states 83

23. Viable Trichuris vulpis eggs in positive samples of drying bed sludges vs. percent moisture content of that sludge: northern states 84

24. Viable Toxocara eggs in positive samples of drying bed sludges vs. percent moisture content of that sludge: northern states 85

25. Viable eggs of Ascaris, Trichuris trichiura, T. vulpis and Toxocara in positive samples of drying bed sludges vs. percent moisture content of that sludge: northern states 86

Number Page

26. Viable *Ascaris* eggs in positive samples of drying bed sludges vs. viable *Ascaris* in positive samples of undigested sludges: northern states 87

27. Viable *Toxocara* eggs in positive samples of drying bed sludges vs. viable *Toxocara* eggs in positive samples of undigested sludges: northern states 88

28. Viable *Ascaris* eggs in positive samples of undigested sludge vs. viable *Ascaris* eggs in positive samples of drying bed sludge: northern and southern states combined 92

29. Viable *Trichuris trichiura* eggs in positive samples of undigested sludge vs. viable *T. trichuria* eggs in positive samples of drying bed sludge: northern and southern states combined 93

30. Viable *Trichuris vulpis* eggs in positive samples of undigested sludge vs. viable *T. vulpis* eggs in positive samples of drying bed sludge: northern and southern states combined 94

31. Viable *Toxocara* eggs in positive samples of undigested sludge vs. viable *Toxocara* eggs in positive samples of drying bed sludges: northern and southern states combined 95

32. Inactivation over time of *Ascaris* eggs by aerobic digestion at different temperatures 104

33. Inactivation over time of *Ascaris* eggs in stabilized sludge after addition of caustic (3200 mg NaOH/g of suspended solids) 106

34. Inactivation over time of *Ascaris* eggs in batch aerobic sludge digesters with different lime dosages run at 25°C 108

35. Inactivation over time of *Ascaris* eggs in sludge previously digested aerobically (25°C and 10 days detention time) after addition of 3200 mg NaOH per g of suspended solids and with varied ammonium dosages 110

36. Inactivation over time of *Ascaris* eggs in sludge previously digested aerobically (35°C and 10 days detention time) after addition of 3200 mg NaOH per g suspended solids and with varied ammonium dosages 112

Number | Page

37. Inactivation over time of Ascaris eggs after different ammonia dosages were added to sludge previously digested aerobically (25°C and 10 days detention time) 114

38. Inactivation over time of Ascaris eggs after different ammonia dosages were added to sludge previously digested aerobically (25°C and 20 days detention time) 115

39. Inactivation over time of Ascaris eggs after different ammonia dosages were added to sludge previously digested aerobically (25°C and 30 days detention time) 116

40. Inactivation over time of Ascaris eggs after different ammonia dosages were added to sludge previously digested aerobically (35°C and 10 days detention time) 119

41. Inactivation over time of Ascaris eggs after different ammonia dosages were added to sludge previously digested aerobically (35°C and 20 days detention time) 120

42. Inactivation of Ascaris eggs exposed to an ultrasonic field of 33 kHz and 600 watt field for different periods of time 122

43. The influence of anionic detergents on the number average of Ascaris eggs recovered from field-collected drying bed sludge samples 141

44. The average number of Ascaris eggs recovered from field-collected drying bed sludge samples, stirred for various periods of time in an anionic detergent, 0.1% Tween 80 . . 142

45. Effects of initial volume of digested sludge sample on the mean percent recovery of Ascaris eggs from anaerobic digested sludges 148

TABLES

Number Page

1. Number of municipal plants in five southern states in which eggs of _Ascaris_, _Toxocara_, _Trichuris trichiura_ and _T. vulpis_ eggs were found (27 plants studied) 8

2. Parasites found in sludge samples form 27 municipal plants in southern United States 9

3. Parasite concentrations in primary and secondary sludge compared to treated sludge. 11

4. Miscellaneous parasites found in sludges from 27 municipal treatment plant samples in five southern states 11

5. Influence of abbatoir waste on parasite concentrations in primary and secondary sludge samples in five southern states 12

6. Parasites having the greatest potential for transmission to man through domestic sludges in the united States . . 12

7. Influence or removal effectiveness of wastewater treatment processes on parasite eggs and cysts 16

8. Percent reduction of viable parasite eggs to total sludge treatment processes 19

9. The relationship between the viability of _Ascaris_ and _Toxocara_ eggs in drying bed sludges and the moisture content of the sludge, in different seasons 20

10. Percentage of plants in Minnesota, New York and Ohio using anaerobic, aerobic and Imhoff digestion 22

11. Percentage of each type of stabilization process selected for sampling in Minnesota, New York and Ohio 23

Number Page

12. Number and percentage of plants in four size categories using anaerobic sludge digestion in Minnesota, New York and Ohio 23

13. Number of plants sampled in four northern states according to stabilization method and dewatering or disposal method used 25

14. Number of plants sampled in four northern states by state and by treatment process 26

15. Number of plants sampled in four northern states by state and by dewatering or disposal methods 26

16. Dates during which treatment plants in Minnesota, New York, Ohio and Washington were sampled 27

17. Number of plants in each northern state in which eggs or cysts of parasites other than *Ascaris*, *Trichuris* or *Toxocara* were found in one or more sludge samples . . . 35

18. Number of treatment plants in each northern state from which eggs of *Ascaris*, *Trichuris trichiura*, *T. vulpis* or *Toxocara* were recovered from any sludge sample according to time of year (season) of sample collection 34

19. *Ascaris* eggs in samples of undigested sludge, sludge from digesters, and postdigestion sludge from wastewater treatment plants in four northern states 35

20. *Trichuris trichiura* eggs in samples of undigested sludge, sludge from digesters, and postdigestion sludge from wastewater treatment plants in four northern states . . . 36

21. *Trichuris vulpis* eggs in samples of undigested sludge, sludge from digesters, and postdigestion sludge from wastewater treatment plants in four northern states . . . 37

22. *Toxocara* eggs in samples of undigested sludge, sludge from digesters, and postdigestion sludge from wastewater treatment plants in four northern states 38

23. Percentage of all sludge samples in each northern state with eggs of *Ascaris*, *Trichuris trichiura*, *T. vulpis* and *Toxocara* 39

24. Percentage of plants in four northern states with eggs of *Ascaris*, *Trichuris trichiura*, *T. vulpis* and *Toxocara* 40

Number Page

25. Density of eggs (viable and nonviable) of *Ascaris*, *Trichuris trichiura*, *T. vulpis*, and *Toxocara* in positive samples of undigested sludges from four northern states in relation to the presence or absence of hog or meat wastes 41

26. Presence or absence of *Ascaris* eggs (viable and nonviable) in undigested sludges samples from four northern states with respect to presence or absence of hog or meat processing wastes 43

27. Densities of eggs of *Ascaris*, *Trichuris trichiura*, Trichuris *vulpis* and *Toxocara* in positive samples of undigested sludges from four northern states 44

28. Densities of eggs of *Ascaris*, *Trichuris trichiura*, *T. vulpis* and *Toxocara* in positive samples of undigested sludges from four northern states as a function of season of sample 45

29. Analysis of the relationship of population, wastes, state and season to the density of viable eggs of *Ascaris*, *Trichuris trichiura*, *T. vulpis* and *Toxocara* in positive samples of undigested sludge from four northern states . . 55

30. Analysis of the relationship of population, wastes, state and season to the density of eggs of *Ascaris*, *Trichuris trichiura*, *T. vulpis* and *Toxocara* (viable and nonviable) in positive samples of undigested sludges of four northern states 55

31. Densities of total *Ascaris*, *Trichuris trichiura*, *T. vulpis* and *Toxocara* eggs in positive samples of undigested sludges from five southern states in relation to the presence or absence of meat processing wastes 59

32. Analysis of the relationship of population, wastes, region and season to the density of total eggs of *Ascaris*, *Trichuris trichiura*, *T. vulpis* and *Toxocara* in positive samples of undigested sludge from four southern regions 59

33. Analysis of the relationship of population, wastes, region and season to the density of viable eggs of *Ascaris*, *Trichuris trichiura*, *T. vulpis* and *Toxocara* in positive samples of undigested sludge from four southern regions 60

34. Analysis of the relationship of population, wastes and region to the density of total eggs of *Ascaris*, *Trichuris trichiura*, *T. vulpis* and *Toxocara* in positive samples of undigested sludges for the north-south combined data set 62

Number Page

35. Analysis of the relationship of population, wastes and region to the densities of viable eggs of *Ascaris*, *Trichuris trichiura*, *T. vulpis* and *Toxocara* in positive samples of undigested sludge for the north-south combined data set 62

36. Densities of total eggs of *Ascaris*, *Trichuris trichiura*, *T. vulpis* and *Toxocara* in positive samples of aerobic, anaerobic and Imhoff digestion sludges in northern states in relation to the presence or absence of meat or hog processing wastes 63

37. Densities of *Ascaris*, *Trichuris trichiura*, *T. vulpis* and *Toxocara* eggs in positive samples of aerobic, anaerobic and Imhoff digestion sludges in four northern states . . 64

38. Densities of eggs of *Ascaris*, *Trichuris trichiura*, *T. vulpis* and *Toxocara* in positive samples of aerobic, anaerobic and Imhoff digestion sludges from four northern states as a function of season of sample collection 66

39. Densities of eggs of *Ascaris*, *Trichuris trichiura*, *T. vulpis* and *Toxocara* in positive samples of aerobic, anaerobic and Imhoff digestion sludges from four northern states, as a function of sludge type 67

40. Analysis of the relationship of population, meat processing, state, digestion and season to the density of viable eggs of *Ascaris*, *Trichuris trichiura*, *T. vulpis* and *Toxocara* in positive samples of aerobic, anaerobic and Imhoff digester sludge from four northern states 76

41. Analysis of the relationship of population, meat processing wastes, state, digestion and season to the density of viable and nonviable eggs of *Ascaris*, *Trichuris trichiura*, *T. vulpis* and *Toxocara* in positive samples of aerobic, anaerobic and Imhoff digester sludge from four northern states 77

42. Decrease in density of viable eggs of *Ascaris*, *Trichuris trichiura*, *T. vulpis* and *Toxocara* in lagoon-stored sludge in two plants in Minnesota 80

43. Analysis of the relationship of percent moisture, sludge age, digestion process and season to the density of viable *Ascaris* and *Toxocara* eggs found in positive samples of drying bed sludges from four northern states 89

Number | Page

44. Number of samples in which there was a reduction in the densities of viable eggs of *Ascaris*, *Trichuris trichiura*, *T. vulpis* and *Toxocara* in drying bed and covered drying samples, as compared to viable egg densities in simultaneous digester samples from plants in four northern states. 89

45. Percent moisture content of drying bed and covered drying bed sludge samples from plants in southern and northern states 90

46. Significance of the relationship of percent moisture content, region, sludge age and digestion to the densities of viable *Ascaris*, *Trichuris trichiura*, *T. vulpis* and *Toxocara* eggs found in positive samples of drying bed sludges from both northern and southern studies 96

47. Methods of sludge disposal used by 48 treatment plants in four northern states 97

48. Percentage of sludge samples destined for disposal in each of four northern states that contained viable eggs of *Ascaris*, *Trichuris trichiura*, *T. vulpis* and *Toxocara* and mean number of eggs of each parasite 98

49. Number of treatment plants in each northern state from which eggs of *Ascaris*, *Trichuris trichiura*, *T. vulpis* or *Toxocara* were recovered from a final sludge sample, according to time of year (season) of sample collection 100

50. Inactivation over time of *Ascaris* eggs in batch aerobically digested sludge 101

51. Inactivation over time of *Ascaris* eggs in a continuous aerobic digestion process at 25°C with a detention time of 10 days 101

52. Inactivation over time of *Ascaris* eggs in a continuous aerobic digestion process at 25°C with a detention time of 20 days 102

53. Inactivation over time of *Ascaris* eggs in a continuous aerobic digestion process at 25°C with a detention time of 30 days 102

54. Inactivation over time of *Ascaris* eggs in a continuous aerobic digestion process at 35°C with a detention time of 10 days 103

Number Page

55. Inactivation over time of Ascaris eggs in a continuous aerobic digestion process at 35°C with a detention time of 20 days 103

56. Inactivation over time of Ascaris eggs in stabilized sludge after addition of caustic (3200 mg N2OH/g suspended solids 105

57. Inactivation over time of Ascaris eggs in batch aerobic sludge digesters with different lime dosages run at 25°C 107

58. Inactivation over time of Ascaris eggs in sludge previously digested aerobically (25°C and 10 day detention time) after the addition of different ammonium sulfate dosages (3200 mg caustic (NaOH)/g of suspended solids or 3000 mg lime/g of suspended solids added to assure ammonia species) 109

59. Inactivation over time of Ascaris eggs in sludge previously digested aerobically (35°C and 10 day detention time) after the addition of different ammonium sulfate dosages (3200 mg caustic (NaOH)/g of suspended solids or 3000 mg lime/g of suspended solids added to assure ammonia species) 111

60. Inactivation over time of Ascaris eggs after the addition of different dosages of ammonia in sludge previously digested aerobically at 25°C with 10, 20 or 30 days detention time 113

61. Inactivation over time of Ascaris eggs after the addition of different dosages of ammonia in sludge previously digested aerobically at 35°C with 10 or 20 days detention time 118

62. Effects of exposure of Ascaris eggs to an ultrasonic field of 33 kHz and 60 watts for 60 minutes 121

63. Results of exposure for different periods of time of Ascaris eggs to an ultrasonic field of kHz and 600 watts 121

64. Summary of results of exposure of intact and decoated Ascaris suum eggs in sludge (3% solids) to varying doses of gamma radiation, CO^{60} source (Double-blind study) 123

Number Page

65. Probable identity of parasites found in sludge samples from 48 wastewater treatment plants in four northern states 124

66. Percentage of sludge samples from four northern states and from five southern states that contained eggs of *Ascaris* spp., *Trichuris trichiura*, *T. vulpis* and *Toxocara* spp. and the mean number of total and viable eggs of each parasite recovered 126

67. Comparison of the efficiency of various flotation solutions for the recovery of *Ascaris* eggs from anaerobic digested sludges 143

68. Effect of specific gravity of $ZnSO_4$ and $MgSO_4$ solutions on the recovery of *Toxocara* eggs from anaerobic digested sludge 144

69. Comparison of the efficiency of various sedimentation procedures following a $ZnSO_4$ flotation procedure on the recovery of *Ascaris* and *Toxocara* eggs from sludge sediment 146

ACKNOWLEDGEMENTS

This investigation could not have been successfully completed without the assistance of Dr. Thomas G. Akers and Mrs. Sharon F. Bock. In addition, the assistance, support and suggestions of Mr. Gerald Stern and Dr. Joseph B. Farrell of the U.S. Environmental Protection Agency's Ultimate Disposal Activities in the Water Engineering Laboratory, and Dr. Norman Kowal and Dr. Herbert Pahren in the Health Effects Research Laboratory, Cincinnati, Ohio, are gratefully acknowledged. Finally, this study could not be completed without the assistance of all state agencies and local municipal plants along with their personnel, and their cooperation was greatly appreciated.

SECTION 1

INTRODUCTION

Results of a one and a half year study on the incidence and persistence of parasites in waste sludges under the EPA research grant indicated that valuable additional information could be obtained by further research in the northern United States.

SECTION 2

CONCLUSIONS

Generally, the influence of sludge handling, treatment and disposal along with the effect of wastewater treatment processes on parasite survival is very complex and influenced by many parameters. Such factors include the type of parasite, temperature, moisture content, digestion process, region, population, industry, etc. This investigation of northern and southern sewage sludges showed that:

1. Resistant stages of numerous parasites of man and animals can be found in untreated and stabilized domestic waste sludges in the northern United States. Stages of 20 types of parasites were found in northern sludges which may represent 25 to 30 different parasites.

2. The most commonly observed parasites in northern sludges, as well as in southern sludges, were the eggs of *Ascaris*, *Trichuris* and *Toxocara*.

3. The parasites occurring in domestic sludges in the United States that pose the greatest risk to human health are the eggs of *Ascaris* spp. (*A. lumbricoides* and *A. suum*), *Trichuris trichiura* and *Toxocara canis*. This conclusion is based on the frequency and densities of these parasites that were found in sludges that are being applied to the land, the ability of these eggs to persist in the environment, and the fact that each of these parasites can produce infection in man.

4. In general, the densities of the total and viable parasite eggs observed in northern domestic waste sludges were lower than those observed in southern sludges.

5. *Ascaris* eggs (total and viable) were found in higher densities in the plants studied in the state of Washington than in the plants studied in Ohio, New York, and Minnesota.

6. In general, the densities of *Trichuris vulpis* and *Toxocara* eggs in undigested sludges were found to decrease as the population served by the treatment plant increased. The densities of *Ascaris*, *Trichuris trichiura*

and *Trichuris vulpis* in digester sludges were found to increase as the population served by the plant increased. At present, there is not a clear explanation of this phenomenon.

7. Overall, the discharge of meat or hog processing wastes into municipal wastewater treatment plants was not associated with increased densities of *Ascaris* eggs, although there was a significant association between the presence of meat processing wastes and samples positive for *Ascaris*.

8. The densities of viable *Ascaris* and *Toxocara* eggs were found to be less in anaerobic digester sludges than in aerobic digester sludges, even though total egg densities showed no such differences. This observation was not surprising since in general the anaerobic digesters ran at higher temperature.

9. Although densities of viable *Ascaris*, *T. trichiura*, *T. vulpis* and *Toxocara* eggs were found to significantly decrease with decreasing moisture content of sludges applied to drying beds, other factors such as age of sludge in the bed, temperature, type of digestion and climate were not significant statistically, but are believed to influence density levels.

The results of laboratory studies on parasite inactivation by aerobic digestion, lime and caustic stabilization, ammonification, ultrasonification, and irradiation with Cobalt 60 indicate the following:

10. Aerobic digestion inactivated *Ascaris* eggs by 30 to 50 percent at a temperature of 35°C over a 10 day period. Sludge age had no influence on the inactivation of *Ascaris* eggs, but by caustic stabilization and ammonification, mesophilic aerobic digestion was noted to enhance inactivation.

11. Lime stabilization produced noticeable inactivation of *Ascaris* eggs. In this study, a more reliable technique for *Ascaris* egg analysis by culturing was utilized. As in our previous study under aerobic conditions at ambient temperatures with dosages of 1,000 mg or greater of lime per gram of dry sludge solids, the viability of *Ascaris* eggs was observed to be reduced by 100% within 10 days.

12. Caustic stabilization (3200 mg of sodium hydroxide per gram of dry sludge solids) revealed two important phenomena: 1) At a hydroxide concentration of 10^{-1} molar (pH-13), the *Ascaris* eggs in 25°C aerobically digested sludges were not inactivated, but 2) when

the temperature was increased to 35°C during the aerobic digestion, all remaining viable Ascaris eggs were subsequently inactivated by caustic stabilization at ambient temperature within ten days.

13. Ammonification with ammonium sulfate at a 0.5 concentration in caustic stabilized sludges resulted in a 100 percent Ascaris egg inactivation in 25°C aerobically digested sludges within ten days. The effectiveness of this inactivation was enhanced by increasing the digestion time or the digester temperature before ammonification with ammonium sulfate.

14. Ammonification with ammonia gas required a dose of one percent ammonia to completely inactivate Ascaris eggs in 25°C aerobically digested sludges within 10 days.

15. Ultrasonication at 600 watts and 33 kHz inactivated 50 percent of the Ascaris eggs after a 1-minute exposure to the ultrasonic field and inactivated 90 percent of the Ascaris eggs after a 12-minute exposure to the ultrasonic field. This high power requirement and long exposure requirement makes ultrasonics economically unfeasible.

16. Irradiation with Cobalt 60 at 200 Krad caused complete inactivation of Ascaris eggs. Also, it was found that the removal of the outer shell of the egg did not alter its sensitivity to radiation.

SECTION 3

RECOMMENDATIONS

The results of this two and one-half year study on the occurrence and densities of parasites in northern sewage sludges indicate that very important additional information can be obtained by further research. The specific areas recommended for additional research on the fate of parasites in wastewater sludges are as follows:

1. The survival of resistant stages of parasites i.e., eggs of *Ascaris*, *Toxocara*, etc. in the soil after the land application of municipal sludges is presently unknown and needs to be studied.

2. The effect of various factors including, method of sludge application, soil type, climate, land usage, sludge treatment, etc., on parasite survival in soil after land application of sludges needs to be evaluated.

3. Following the above studies, the degree of health risks to humans and animals should be determined with respect to different field situations, i.e., type of sludge and method of application, intended land use, climate, etc.

4. After the above are completed, a rational management and sludge treatment scheme can be developed. These plans should consider proper inactivation techniques. safety of personnel in contact with sludge before and after land application, and crop and livestock control.

5. A field study should be conducted to ascertain the effectiveness of long-term lagoon storage of sludge in warm climates for the inactivation of parasite eggs and other pathogens.

6. A similar field study should be conducted for drying beds. These studies should investigate the factors that are likely to affect the fate of parasites, i.e., sludge type, sludge age, temperature, moisture content, and climate, etc.

7. The results of this and other studies indicate that

composting might be an effective way of disinfecting sludge. Field studies should be initiated to look at various composting processes and the influence of the following parameters: temperature, sludge type, exposure time, etc.

Recent studies support potential viable alternatives for parasite decontamination of sludges. Five such alternatives recommended for further investigation are:

1. Ammonification using intermediate dosages
2. Lime-stabilization with ammonia additions
3. Sludge drying beds, evaluating the effects of various factors, such as moisture, temperature, sludge type, etc., on parasite inactivation.
4. Composting
5. Aerobic digestion at intermediate temperatures

The choice of one or more of these five alternatives would be based on economics, low maintenance and energy requirements, effectiveness of treatment, and ease of incorporation into current sludge stabilization techniques.

Finally, the potential health risks due to the presence of infectious agents in sludge should be determined.

SECTION 4

PARASITES IN SLUDGE

The problems associated with the occurrence of human and animal parasites in domestic wastewater sludges received little attention in the United States prior to 1970. Several workers had examined wastewater effluents and sludges from municipal plants in different parts of the country and had found the eggs of several intestinal helminths. However, the techniques used to recover the parasites and to quantitate them varied from study to study. Consequently, the results of these studies had little practical value other than recording the presence of the parasites found.

Fox, Fitzgerald and Lue-Hing conducted a comprehensive study of parasites in raw sewage, anaerobically digested sludges and effluents from the Metropolitan Sanitary District of Greater Chicago (8). Hayes examined raw and digested sludges from four wastewater plants in Allegheny Co., Pennsylvania (1). Theis et al. examined municipal sludges (raw, digested, and composted) from 12 localities in the states of California, Missouri, Wisconsin, Indiana, Ohio and Georgia (9). Chaney and Burge examined liquid sludges from 16 municipalities in various parts of the United States (10).

After 1970, several regulations related to the treatment of domestic wastewater (the Clean Water Act of 1972 and its 1977 Amendments) and the disposal of sewage sludges (the Resource Conservation and Recovery Act of 1976) were enacted. The stricter requirements for the treatment of wastewater has led to a magnitudal increase in the production of domestic sewage sludge and the problems related to the disposal of these sludges have increased accordingly. The land application of sludge is one disposal method that has attracted considerable interest and has been increasingly used in the past few years with the encouragement of governmental agencies. However, the health effects to humans and animals when sludges are applied to the land have yet to be fully evaluated. The assessment of the health risks associated with the land application of wastewater sludges has been the subject of several recent symposia (5-7). In addition, federal and municipal agencies have provided support for numerous research studies on the potential health effects of the toxic chemicals and infectious agents in sludge. Most of the studies have been concerned with viruses, bacteria and fungi. In contrast, there have been relatively few studies on the parasites that occur in sludge.

In the most comprehensive of all the studies carried out in the United States, Reimers et al. (11) collected sludge samples during each of the four seasons from 27 municipal wastewater treatment plants located in five southern states (Alabama, Florida, Mississippi, Louisiana and Texas) and examined them for the presence and density of human and animal parasites. The parasites found in sludges examined in this study are listed in Table 2. With the exception of the eggs of *Enterobius vermicularis*, the human pinworm, the list includes all of the parasites found in sludges in the previously mentioned studies (1, 8-10).

In the study of Reimers *et al.*, they reported that *Ascaris*, *Toxocara*, *Trichuris trichiura*, and *Trichuris vulpis* were the most commonly found parasites (11). The eggs of *Ascaris*, *Toxocara* and *T. vulpis*, either viable or dead, were found at least once in every plant studied, and *T. trichiura* eggs were found at least once in all but one of the plants (Table 1). Viable eggs of *Ascaris*, *Toxocara*, *Trichuris vulpis* and *T. trichiura* were recovered at least once from treated sludges from 26, 23, 25 and 12 plants, respectively. The concentration of viable and nonviable eggs of *Ascaris*, *T. trichiura*, *T. vulpis* and *Toxocara* found in primary and secondary sludge as compared to treated sludge is shown in Table 3. Primary and secondary treated sludge samples were found to contain the following in order of decreasing average densities: 9,700 *Ascaris* eggs, 1,200 *Toxocara* eggs, 800 *T. trichiura* eggs and 600 *T. vulpis* eggs/kg dry weight of sample. The average numbers of these parasites in treated sludge samples were: 9,600 *Ascaris* eggs, 2,600 *T. trichiura* eggs, 700 *Toxocara* eggs and 700 *T. vulpis* eggs/kg dry weight of sludge sample. The densities of these parasites varied greatly from sample to sample with the standard deviation being greater than the observed average in each case. The largest number of eggs observed in any sample was 230,000 *Ascaris* eggs/kg dry weight. The percentage of the total parasite eggs in individual sludge samples that were viable ranged from 0% to 100%. Of the total number of eggs of each of the four most commonly found parasites, at least 45% were viable. The viability of eggs tended to be higher in the primary and secondary sludges, but, in the case of *Ascaris*, 69% of the eggs in treated sludges were viable while only 45% of the eggs in primary and secondary sludges were viable.

TABLE 2. NUMBER OF MUNICIPAL PLANTS IN FIVE SOUTHERN STATES IN WHICH EGGS OF *ASCARIS*, *TOXOCARA*, *TRICHURIS TRICHIURA* AND *TRICHURIS VULPIS* WERE FOUND (27 PLANTS STUDIED) (11)

Parasite	Fall[1]	Winter	Spring	Summer	Entire year
Ascaris	17[2]/25[3]/26[4]	22/25/26	14/26/27	14/25/25	26/27/27
Toxocara	11/22/24	17/27/27	9/24/24	9/23/25	23/27/27
Trichuris trichiura	6/10/16	8/12/19	7/10/16	6/10/16	12/15/26
Trichuria vulpis	19/21/22	19/23/24	19/23/26	12/24/25	25/26/27

[1] Samples from only 26 plants examined in the fall.

[2] Number of plants in which viable eggs were found in treated sludge.

[3] Number of plants in which viable eggs were found in any sludge sample.

[4] Number of plants in which viable or nonviable eggs were found in any sludge sample.

TABLE 2. PARASITES FOUND IN SLUDGE SAMPLES FROM 27 MUNICIPAL PLANTS IN SOUTHERN UNITED STATES (11)

Parasite found	Probable identity	Definitive host
Ascaris eggs	*Ascaris lumbricoides*[1]	Humans
	Ascaris suum[1]	Pigs
Toxocara eggs	*Toxocara canis*[2]	Dogs
	Toxocara cati[2]	Cats
Trichuris trichiura-like eggs	*Trichuris trichiura*	Humans
	Trichuris suis[3]	Pigs
Trichuris vulpis eggs	*Trichuris vulpis*	Dogs
Toxascaris-like eggs	*Toxascaris leonina*	Dogs and cats
Ascaridia-like eggs	*Ascaridia galli*	Domestic poultry
	Heterakis gallinae	Domestic poultry
Trichosomoides-like eggs	*Trichosomoides crassicauda*	Rats
	Anatrichosoma buccalis	Opossums
Cruzia-like eggs	*Cruzia americana*	Opossums
Capillaria spp. eggs (3 or more types)	*Capillaria hepatica*	Rats
	Capillaria gastrica	Rats
	Capillaria spp.	Domestic poultry
	Capillaria spp.	Wild birds
	Capillaria spp.	Wild mammals
Hymenolepis diminuta eggs	*Hymenolepis diminuta*	Rats
Hymenolepis nana eggs	*Hymenolepis nana*	Humans and rodents
Hymenolepis spp. eggs	*Hymenolepis* spp. (poss. more than one species)	Domestic and/or wild birds
Taenia spp. eggs	*Taenia saginata*[4]	Humans
	Taenia pisiformis[4]	Cats
	Hydatigera taeniaeformis[4]	Dogs
Acanthocephalan eggs	*Macracanthorhynchus hirudinaceus*	Pigs
Entamoeba coli-like eggs	*Entamoeba coli*[5]	Humans
	Entamoeba spp.	Rodents, etc.

TABLE 2 (continued)

Parasite found	Probable identity	Definitive host
Giardia cysts	Giardia lamblia	Humans Dogs, cats, mammals
Coccidia oocysts	Isospora spp. Eimeria spp.	Dogs and cats Domestic and wild birds, mammals

[1] Eggs of A. lumbricoides and A. suum are indistinguishable.
[2] Toxocara eggs were probably mostly T. canis.
[3] T. suis eggs were probably only rarely seen.
[4] Eggs of these worms are indistinguishable.
[5] An intestinal amoeba that is a commensal, not a parasite.

Reimers et al. (11) found that the densities of these parasites eggs differed in sludges from municipal plants located in various climatic regions. In sludges from plants located in the coastal regions of the five states studied, the eggs of Ascaris and T. trichiura, which were presumed to be mostly from humans, were present in higher numbers than they were in sludges from plants located in the drier areas away from the Gulf Coast. On the other hand, the numbers of eggs of Toxocara spp. and T. vulpis, parasites of dogs and cats, did not vary much in sludges from the different geographic regions.

The other parasites found in the study by Reimers et al. (11) and the number of plants in which viable or nonviable forms were found are listed in Table 4. These parasite eggs and cysts when found were in low concentrations. Of these parasites, Hymenolepis diminuta, the rat tapeworm, was most frequently found; its eggs were observed in 23 of the 27 plants studied. However, viable eggs of H. diminuta were only found in the primary sludges of 15 plants and the treated sludges of 4 plants.

Reimers et al. (11) found unusually high levels of Ascaris eggs in the sludges of one wastewater treatment plant. A detailed study revealed that an abbatoir in the community processed large numbers of swine and the wastes from this abattoir entered the municipal sewer system. The levels of parasite eggs in wastewater treatment sludges receiving the abattoir wastes were compared with six other wastewater treatment plants of similar size in the same geographic area. (Table 5). In the plant receiving abattoir wastes, an average of 81,000 Ascaris eggs/kg dry weight of sludge was recovered, while in the 6 plants receiving little or no abattoir wastes an average of 7,900 Ascaris eggs/kg was recovered. The Ascaris eggs in the treatment plant receiving the abattoir wastes were undoubtedly mostly A. suum eggs that came from infected swine. It is interesting that the level of T. trichiura-like eggs was nearly the same in each plant. This would indicate that very few, if any, of these eggs were those of T. suis, the swine whipworm.

TABLE 3. PARASITE CONCENTRATIONS IN PRIMARY AND SECONDARY SLUDGE AS COMPARED TO TREATED SLUDGE (11)

Parasite	Nature of sludge[1]	Average[2]	Standard deviation	Range	Percent viable eggs
Ascaris spp. (human and pig roundworm)	Primary and secondary	9,700	26,300	200,000-0	45
	Treated	9,600	27,400	230,000-0	69
Trichuris trichiura (human whipworm)	Primary and secondary	800	2,900	26,000-0	50
	Treated	2,600	9,800	84,000-0	48
Trichuris vulpis (dog whipworm)	Primary and secondary	600	1,000	5,700-0	90
	Treated	700	1,300	10,500-0	64
Toxocara spp. (dog and cat roundworm)	Primary and secondary	1,200	2,300	5,400-0	88
	Treated	700	1,500	8,500-0	52

[1] Primary and secondary sludges include sludges from primary clarification, Imhoff digestion, activated sludge, contact stabilization, and extended aeration. Treated sludges include sludges from mesophilic aerobic and anaerobic digestion, vacuum filtration, centrifugation, lagoons and drying beds.

[2] Numbers rounded off to nearest 100.

TABLE 4. MISCELLANEOUS PARASITES FOUND IN SLUDGES FROM 27 MUNICIPAL TREATMENT PLANT SAMPLES IN FIVE SOUTHERN STATES (11)

Parasite	No. of plants in which found
Toxascaris leonina eggs	2
Ascaridia-like eggs	7
Cruzia-like eggs	1
Trichosomoides-like eggs	7
Capillaria eggs (shells with pits)	7
Capillaria eggs (shell with striations)	11
Hymenolepis diminuta eggs	23
Hymenolepis nana eggs	6
Taenia sp. eggs	1
Acanthocephalan eggs	1
Entamoeba coli-like eggs	23
Giardia cysts	9
Coccidia oocysts	6

TABLE 5. INFLUENCE OF ABBATOIR WASTES ON PARASITE CONCENTRATIONS IN PRIMARY AND SECONDARY SLUDGE SAMPLES IN FIVE SOUTHERN STATES (11)

Parasite eggs	Significant source contribution	Average no. of viable and nonviable eggs/kg dry weight of sludge[1]
Ascaris spp. (human and pig roundworms)	Domestic[2]	7,900
	Abattoir[3]	81,800
Trichuris trichiura	Domestic	1,500
or		
Trichuris suis (human or pig whipworms)	Abattoir	1,600
Toxocara spp. (dog and cat roundworms)	Domestic	1,800
	Abattoir	500

[1] Numbers rounded off to the nearest 100.

[2] Six domestic plants found in the geographical area.

[3] A single treatment plant in the geographical area receiving waste from large swine slaughter and packing houses.

TABLE 6. PARASITES HAVING THE GREATEST POTENTIAL FOR TRANSMISSION TO MAN THROUGH DOMESTIC SLUDGES IN THE U.S. (11,12)

Parasite	Stage	Definitive host	Intermediate host
Ascaris lumbricoides	Egg	Man	"Soil"
Ascaris suum	Egg	Pig	"Soil"
Toxocara canis	Egg	Dog	"Soil"
Toxocara cati[1]	Egg	Cat	"Soil"
Trichuris trichiura	Egg	Man	"Soil"
Trichuris suis[1]	Egg	Pig	"Soil"
Trichuris vulpis[1]	Egg	Dog	"Soil"
Taenia saginata	Egg	Man	Cow
Taenia solium	Egg	Man	Pig (Man)
Echinoccus granulosus	Egg	Dog	Sheep, pig, etc. (Man)
Toxoplasma gondii	Oocysts	Cat	"Soil", Mammals, (Man)

[1] Medical importance questionable.

Although the number of parasite species found in sewage sludges in the United States may exceed 30 (see Table 2), the number that is likely to be transmitted through sludge to man is much less. The parasites that would seem to have the greatest potential for transmission through domestic wastewater sludges to man, and in some cases to animals, are listed in Table 6. Each of the parasites listed have a resistant stage that may survive standard wastewater treatment processes. For the first seven parasites, the resistant stage is an egg that must undergo development in the soil before it becomes infective for the definitive host or man. The minimum time required for this development varies somewhat with the parasite and depends on the presence of favorable environmental conditions (sufficient moisture and oxygen and optimum temperature), but is approximately two to four weeks. The eggs of *Taenia saginata*, *Taenia solium* and *Echinococcus granulosus* are already infective when passed in the feces of the host and are likely to still be infective when they enter sewage. The oocysts of *Toxoplasma gondii* are not infective when passed in the feces of cats but can develop to the infective stage in about 3 to 4 days under suitable environmental conditions.

Of the human parasites on this list, the eggs of *Ascaris* spp. are the ones that are most commonly found in raw and stabilized sludges in this country (1, 8-11), and are probably the most important ones. The *Ascaris* egg is resistant to a wide range of chemical and physical conditions and is generally considered to be the most resistant form of any parasite. *Ascaris* eggs have been reported to persist in the soil for over five years (13,14) and are capable of surviving longer in sewage sludges and in the soil than most bacteria, viruses, and fungi (15). For this reason *Ascaris* is often used as an indicator organism in monitoring the effectiveness of sludge treatment processes or disinfection procedures other than irradiation. Although the eggs of the other helminths on the list are apparently less resistant than those of *Ascaris*, they are nevertheless capable of surviving for months or years under favorable conditions. The oocysts of the protozoan *Toxoplasma gondii* are also quite resistant. They have been reported to survive for at least 18 months in the soil under natural conditions (16).

All of the parasites listed in Table 6 are capable of producing disease in man. The nature of the disease produced in man by these parasites has been discussed in recent publications (11,12).

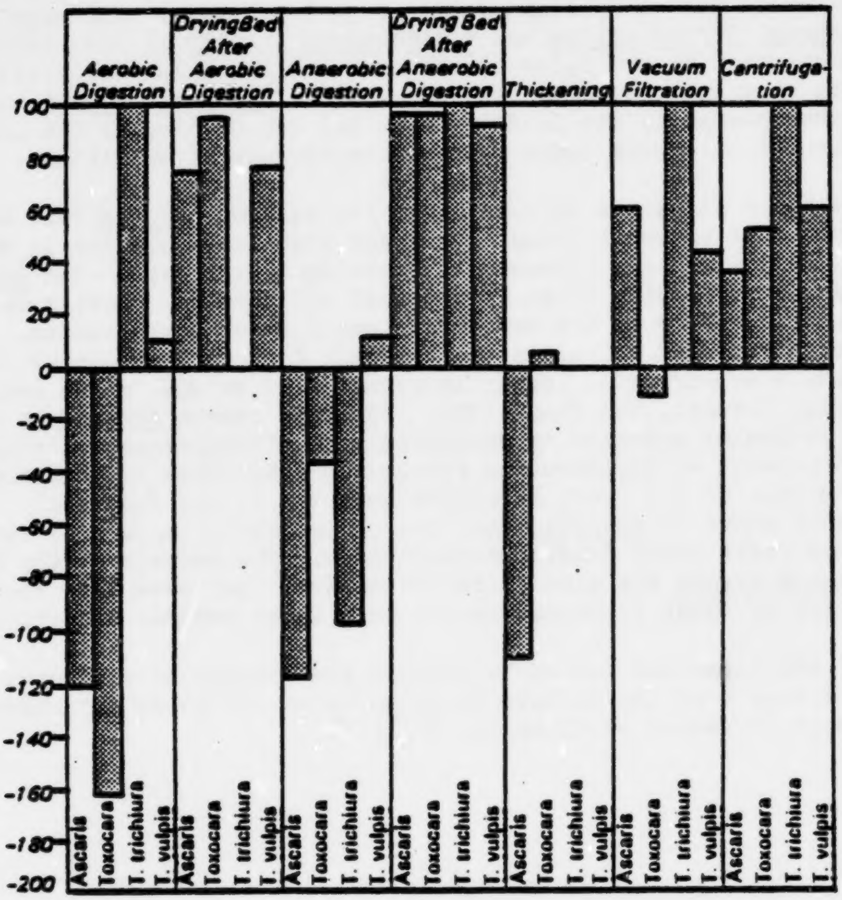


Figure 1: Average percent of viable parasite eggs by unit process. (Negative values indicate that densities of parasites increased after the process.)

WASTEWATER TREATMENT PROCESSES

The conventional domestic wastewater treatment processes can be divided into three categories: 1) removal processes (removing contaminants from wastewater); 2) stabilization processes (decreasing bulk organics, odor, and pathogen content of sludges); and 3) inactivation processes (making the handling and disposal of sludges safer and more economical). These three major categories also have been found to affect parasites in different ways (Table 7).

Because parasite eggs and cysts are relatively heavy as compared to water they are concentrated along with the solids by removal processes. In general, processes that remove solids have been observed to be up to 90% effective in the removal of parasites with the one major exception being the trickling filter which actually does not filter the sludge. In the latter case, parasite removal occurs in the clarifier following the trickling filter. In sludge stabilization processes, aerobic or anaerobic environments are produced which may or may not reach lethal temperatures. Because most parasite eggs and cysts require an oxygen level above that of the gut in the host for development, anaerobic digesters tend to retard their development while aerobic digesters tend to accelerate it. As expected, these processes will kill the eggs if either the anaerobic or aerobic processes are carried out at temperatures which are lethal to parasites (> 55°C). Some sludge dewatering and disinfection processes will destroy the eggs by increasing the temperature, as in incineration and composting, or by greatly reducing the moisture content, as in some drying beds. In more exotic cases, eggs may be destroyed by disruption of their biological subunits with sonication, radiation, or microwaves.

The results of investigations recently carried out by Reimers _et al_. (11) on parasites in southern domestic sludges indicate that, in general, conventional sludge stabilization processes (e.g., mesophilic anaerobic or aerobic digestion) are not very effective in destroying parasite eggs (see Figure 1). The number of viable _Ascaris_ and _Toxocara_ eggs per unit dry weight of sludge was found to increase after these treatment processes due to the loss of dry mass of sludge solids. However, drying beds were found to be consistently effective in destroying parasites in sludges.

Reimers _et al_. (11) collected data on both raw sludges (undigested sludges) and sludges from drying beds following stabilization by either aerobic digestion or anaerobic digestion under ambient or mesophilic temperatures (Table 8). The densities of the viable eggs of each parasite were reduced more in the summer and spring than in the fall and winter. While the reduction in viable eggs was less during the winter in anaerobically digested sludges, in aerobically digested sludges, a seasonal fluctuation was noted only for _T_. _trichiura_.

Reimers _et al_. (11) also found a correlation between the density of viable parasites and the moisture content in drying bed sludges. Figure 2 shows the correlation of the logarithms of the number of viable _Ascaris_ eggs in raw and drying bed sludges, respectively, in the same plants

TABLE 7. INFLUENCE OR REMOVAL EFFECTIVENESS OF WASTEWATER TREATMENT PROCESSES ON PARASITE EGGS AND CYSTS

Unit operation	Effectiveness	Sources
	Removal processes (no parasite destruction): 30-99% removal	15,17
Clarifiers (Primary and Secondary)	Removal depends on operating conditions	19
Flotation	< 95% Removal (depends on stage of egg (and operating conditions)	19
Imhoff tanks	97% removal	20
Trickling filtration	38% removal (promotes egg development)	15,21,22
Filtration	< 99% of eggs	13,11,12,8
Oxidation ditch	50-<99% removal	8,14,15,24
Aerated lagoons	75-95% removal	24
Activated sludge	50-<99% removal	15
Waste stabilization lagoons	< 99% removal	15
Septic tanks	50-90% removal	15
Tertiary lagoons	< 99% removal	15
Land application	< 99% removal	15
	Stablization processes (affecting parasite development):	
Anaerobic digesters	Retards egg development (increased destruction with increase temperature)	9,11,12,15
Activated sludge	Promotes egg development	17,18
Extended aeration	Promotes egg development	17
Aerobic Digesters	Promotes egg development (increased destruction with increased temperature)	11

TABLE 7 (Continued)

Unit operation	Effectiveness	Sources
Stabilization processes (affecting parasite development):		
Agricultural application	Promotes egg development	15
Decontamination processes (possible egg destruction):		
Incineration	100% destruction	
Vacuum filtration	No effect	
Centrifugation	No effect	
Drying beds	100% kill at < 5% moisture content (moisture content may vary with temperature)	17
Composting	100% effective is all matter reaches 60°C for at least 2 hours	26,27
Routine chlorination	No effect	23,28
Sonication	Possibly, but not effective on Ascaris at 800 KH_z and 150 watts	29
Gamma Radiation	Not 100% effective (depends on stage of egg and irradiation dose)	30,31
Heat	100% effective at about 70°C for 30 minutes or in less time at higher temperatures (effectiveness depends on temperature and exposure time but temperatures below 45°C appear to have little effect)	23,27,32
Lagoon storage	50-100% (depends on time)	23,34,35
Lime stabilization	80 to 100% (depends on digestion, time, and temperature)	11
Ammonification	Up to 95% (depends on dosage and pH)	11

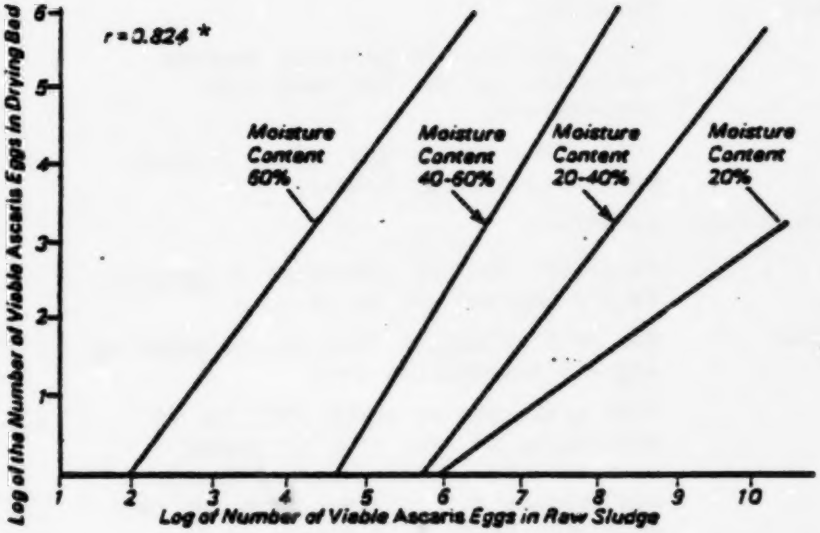


Figure 2: Plot of log of number of viable Ascaris eggs in raw sludge grouped by moisture content of drying bed sludges.

*Value for all lines

TABLE 8. PERCENT REDUCTION OF VIABLE PARASITE EGGS BY TOTAL SLUDGE TREATMENT PROCESSES[1] (11)

Process period	*Ascaris*	*Toxocara*	*T. trichiura*	*T. vulpis*
Total	67/76/69[2]	91/28/74	39/118/26	44/87/58
Fall	58/101/16	82/39/16	31/87/7	(1)[3]/135/8
Winter	36/108/17	89/37/22	(26)/196/7	7/108/16
Spring	87/16/18	95/14/19	80/28/6	70/41/18
Summer	84/26/18	98/6/17	93/15/5	74/49/16
Aerobic	70/45/13	90/21/16	(25)/105/4	63/46/11
Fall	97/5/3	69/34/3	(66)/-/1	81/-/1
Winter	34/60/4	98/31/4	(155)/-/1	48/74/2
Spring	82/37/4	88/25/5	54/-/1	63/44/4
Summer	80/29/2	100/0/4	67/-/1	68/54/4
Anaerobic	66/83/55	91/31/55	52/119/21	34/96/43
Fall	49/111/13	83/42/12	48/82/6	(31)/145/6
Winter	37/121/13	86/42/17	(5)/206/6	(7)/113/13
Spring	89/24/14	98/6/14	85/27/5	71/42/13
Summer	84/28/15	97/7/12	100/0/4	74/51/11

[1] Aerobic or anaerobic digestion follwed by drying beds

[2] Average/standard deviation/number of samples.

[3] Numbers in parenthesis indicate percent increase.

(grouped by the moisture content of the drying bed sludges). The inactivation of parasite eggs increased with decreasing moisture content of the drying bed sludges. The densities of viable *Ascaris* and *Toxocara* eggs in the drying bed sludges, as related to the sludge moisture content, were analyzed for each season. The lowest moisture level at which all *Ascaris* or *Toxocara* eggs were inactivated was 5% in the fall, 7% in the winter, 8% in the spring and 15% in the summer (Table 9). Evidently, both temperatures and reduction in moisture content played a part in the inactivation of these parasites.

Only a few observations have been made concerning the presence and survival of helminthic eggs in lagoon-stored sludge in this country. Arther examined sludge from lagoons of the Chicago Sanitary District in Fulton County, Illinois, on four occasions from May, 1976 to October, 1977 (33). He recovered an average of 203 *Ascaris*, 173 *Toxocara*, 48 *Toxascaris leonina* and 36 *Trichuris* eggs per 100 g dry weight. When the recovered eggs were cultured, the percentage of eggs developing to the infective stage was

24% for *Ascaris*, 10% for *Toxocara*, 43% for *Toxascaris leonina*, and 6% for *Trichuris*. Unfortunately, this author provided no information on the length of time the sludge had been stored in a lagoon.

TABLE 9. THE RELATIONSHIP BETWEEN THE VIABILITY OF *ASCARIS* AND *TOXOCARA* EGGS IN SOUTHERN DRYING BED SLUDGES AND THE MOISTURE CONTENT OF THE SLUDGE, IN DIFFERENT SEASONS (11)

Season	No. of drying bed samples analyzed	No. of samples with no viable eggs	Lowest moisture contents below which no viable eggs observed	No. of samples with no viable eggs at or below lowest moisture contents	No. of samples with viable eggs
For both *Ascaris* and *Toxocara* eggs					
Fall	24	7	5%	1	17
Winter	22	4	7%	1	18
Spring	22	12	8%	8	10
Summer	21	14	15%	8	7
For only *Ascaris* eggs					
Fall	24	7	5%	1	14
Winter	22	5	7%	1	17
Spring	22	12	8%	8	10
Summer	21	14	15%	8	7
For only *Toxocara* eggs					
Fall	24	12	5%	1	12
Winter	22	12	21%	3	10
Spring	22	17	21%	11	5
Summer	21	18	20%	10	3

Reimers *et al*. (11) examined only one sample of lagoon-stored sludge. This was collected from a plant in central Mississippi on the first trip to the plant. On the subsequent trip, it was learned that the plant had terminated the procedure of storing sludge in lagoons, so no additional samples were taken from the lagoons. From the sample, the following eggs were recovered (number per 100 gm dry weight and percent that appeared to be viable by morphologic criteria): *Ascaris*, 1730 (13% viable); *Trichuris trichiura*, 21 (0% viable); *T. vulpis*, 192 (78% viable); and *Toxocara*, 230 (0% viable). It is not known how long these eggs had been in storage, but the lagoons were designed to store sludge for three years.

Although little information is available on the survival of helminth eggs in lagoon-stored sludge, the results of laboratory experiments in which helminth eggs were stored in digested sludges at 4°C and 25°C were recently reported (34,35). Complete inactivation of *Ascaris suum* eggs was observed in both aerobically and anaerobically digested sludges after 20 months storage at 25°C. Under the same conditions *Toxocara canis* and *Trichuris vulpis* eggs were 100% inactivated much earlier. However, when stored at 4°C, *A. suum* eggs were still viable after storage for two years. The die-off of selected bacteria and viruses including some pathogens has been found to occur at a greater rate than the eggs of *Ascaris* under the same conditions (36). At temperatures of 20°C or greater, the minimum time required to obtain a density reduction of one log was found to be about one month for bacteria and two months for viruses. At temperatures less than 20°C, the storage time required to achieve the same level of reduction was more than six months for bacteria and more than eight months for viruses.

There have been conflicting observations concerning the destruction of parasite eggs by irradiation. After a gamma radiation dosage of 100 Krad from a Cobalt 60 source was applied to sludge containing *Ascaris* eggs, only 0.7 to 1 percent of the eggs were still infective, yet even at dosages of 500 Krad, complete inactivation did not occur (31). In another study (30), using gamma radiation from a 12,000 Ci Cobalt source, dosages of 400, 800, 1200, and 1800 Krad had no effect on *Parascaris equorum* (= *Ascaris megocephala*) which still had their outer coat, while all four dosages killed the *P. equorum* eggs without outer shells. Finally, investigations at Sandia Laboratories noted a 99.9% destruction of *Ascaris* eggs from the uteri of worms with their outer shell oxidized off at 150 Kilorads (37). The question as to whether the nature of the *Ascaris* egg's outer shell affects their susceptibility to gamma radiation still has not yet been resolved.

Reports on the use of ultrasound for the inactivation of pathogenic microorganisms indicate that, in general, ultrasound is an economical and feasible method of disinfection only when used in conjunction with other techniques such as applying heat or adding ozone, peroxide, etc., although disinfection has been noted when ultrasound is used alone (38-47). The results of a recent study indicate that disinfection by ultrasound is a function of intensity of the sonic waves, not the frequency. For example, *Escherichia coli* B is inactivated only if the intensity is kept at 2.25 watts/cm^2 or greater (42,46). Most researchers have observed some inactivation of microbes by ultrasonics alone, but none were able to obtain complete inactivation (100 percent kill). In the activation of bacteria and fungi, regrowth of the organisms is an additional problem (43,45). At present, ultrasonification appears to have potential as a disinfection process, and in the near future, the synergistic use of heat and/or chemicals (oxidants-ozone or chlorine-or biocides-pesticides) will possibly make these processes economically feasible (40, 41 and 48). It was recently observed in this laboratory that ultrasonification is one of the few physical techniques that will inactivate most parasites except *Ascaris* when used at very low intensities (< 75 watts).

SECTION 5

PART I. PARASITES IN SLUDGES IN NORTHERN STATES AND LABORATORY EVALUATION OF DISINFECTION TECHNIQUES

METHODOLOGY

Field Studies and Evaluation

Method of Plant Section--

The appropriate governmental agency in each of the four states in this study was contacted and asked to send information about the treatment plants within its state. The information requested included the size and location of the plants, type of treatment, and any other information the states would care to supply. Information received from New York, Ohio, and Minnesota is summarized in Tables 10-12. The state of Washington was unable to provide such information.

TABLE 10. PERCENTAGE OF PLANTS IN MINNESOTA, NEW YORK AND OHIO USING ANAEROBIC, AEROBIC AND IMHOFF DIGESTION

	MINN.		NEW YORK		OHIO	
Digestion process	No. of plants	Percentage of total	No. of plants	Percentage of total	No. of plants	Percentage of total[1]
Anaerobic	100	61%	228	64%	170	58%
Aerobic	16	10%	54	15%	45	15%
Imhoff	47	29%	77	21%	79	27%

Additional Miscellaneous Treatment Processes by State

MINNESOTA:	Chemical sludge treatment	18 plants
	Liming of sludge	1 plant
	High rate digestion	1 plant
NEW YORK:	Zimpro	1 plant
	Liming of sludge	1 plant
OHIO:	Liming of sludge	1 plant
	Chemical sludge treatment	1 plant
	Zimpro	1 plant

---

[1] Excluding plants with stabilization ponds, no dewatering, lagoons, no digestion, etc.

TABLE 11. PERCENTAGE OF EACH TYPE OF STABILIZATION PROCESS SELECTED FOR SAMPLING IN MINNESOTA, NEW YORK AND OHIO

Process	Percentage of Total
Anaerobic digestion	66.8%
Aerobic digestion	16.6%
Imhoff digestion	16.6%

TABLE 12. NUMBER AND PERCENTAGE OF PLANTS IN FOUR SIZE CATEGORIES USING ANAEROBIC SLUDGE DIGESTION IN MINNESOTA, NEW YORK AND OHIO

	MINN		NEW YORK		OHIO		TOTAL	
Size category	No. of plants	Percent of total	No. of plants	Percent of total	No. of plants	Percent of total	No. of plants	Percent of total
< 50 MGD	1	1%	15	8%	4	2%	20	4%
10-50 MGD	2	2%	12	6%	5	3%	19	4%
1-10 MGD	16	16%	87	45%	76	43%	179	38%
< 1 MGD	82	81%	79	41%	93	52%	254	54%
TOTAL	101		193		178		472	

After considering the information, the types of treatment processes and the percentage of each that were to be sampled in the northern states were formulated. Also, the sizes of the plants were considered. It was determined that size categories would only be useful for anaerobic types of treatment, and the size categories that were decided on were: < 1, 1-10, and > 50 MGD. Where the size of the plants was expressed as the population served, the service of 10,000 people was considered to represent 1 MGD. Also, to gain knowledge about the size of the plants as it related to types of parasites, it was decided that equal numbers of plants in each of the different size categories of anaerobic digestion would be sampled; most of the Imhoff and aerobic digestion processes were, of course, used at smaller plants.

The number of plants to be sampled in each state was based on the number of man-hours required for the parasitologic analysis. It was estimated that no more than forty samples could be processed per week. Since only one week could be allowed between trips to the different states, only forty samples per state could be examined. Since three samples were to be collected from each plant, only 13 plants from each state could be examined. To allow for cases where more than three samples would have to be collected from any certain plant, it was decided that 12 plants from each state would be surveyed.

The final process of plant selection involved the determination of the poststabilization or dewatering methods and other interesting treatments that would be sampled. With interest in the effects of numerous methods, plants using several different methods were considered for examination. The methods used included: drying beds, covered drying beds, vacuum-filtered sludges, centrifuged sludges, limed sludges, and sludges that were treated with the Zimpro process. Also of interest were plants that trucked the sludge in liquid form or barged it to the ocean, so these were also included in the study.

When the data from the state of Washington did arrive, it was found that this state was much different than the other three in that it had no Imhoff plants and no very small treatment plants. Therefore, it was decided to contact more small, 1-10 MGD, anaerobic digestion plants in this state.

The number of plants sampled in each of these four states, broken down by stabilization process and dewatering method, is shown in Table 13. The data on the type of stabilization process sampled in each state is shown in Table 14, and the types of dewatering methods sampled in each state is shown in Table 15.

TABLE 13. NUMBER OF PLANTS SAMPLED IN FOUR NORTHERN STATES ACCORDING TO STABILIZATION METHOD AND DEWATERING OR DISPOSAL METHOD USED

		Dewatering or Disposal Method							
Stabilization method	Total	Drying beds	Covered drying beds	Trucked as liquid	Vacuum filter	Barged to ocean	Centrifuge	Lagoon	Compost
Anaerobic digestion									
> 50 MGD	6	0	0	0	2	2	1	1	0
10-50 MGD	8	3	1	3	0	0	0	0	1
1-10 MGD	11	7	1	2	1	0	0	0	0
< 1 MGD	6	4	1	1	0	0	0	0	0
Imhoff digestion	6	5	1	0	0	0	0	0	0
Aerobic digestion	8	6	1	1	0	0	0	0	0
Limed sludge	2	0	0	0	1	0	0	1	0
Zimpro process	1	0	0	0	1	0	0	0	0
TOTAL	48	25	5	7	5	2	1	2	1

TABLE 14. NUMBER OF PLANTS SAMPLED IN FOUR NORTHERN STATES BY STATE AND BY TREATMENT PROCESS

Stabilization method	STATE			
	MINN.	NEW YORK	OHIO	WASH.
Anaerobic digestion				
> 50 MGD	1	2	1	2
10-50 MGD	2	2	2	2
1-10 MGD	2	2	2	5
< 1 MGD	2	2	2	0
Imhoff digestion	2	2	2	0
Aerobic digestion	2	2	2	2
Limed sludges	0	1	0	1
Zimpro process	0	0	1	0
TOTAL	11	12	13	12

TABLE 15. NUMBER OF PLANTS SAMPLED IN FOUR NORTHERN STATES BY STATE AND BY DEWATERING OR DISPOSAL METHODS

Dewatering or Disposal method	STATE			
	MINN.	NEW YORK	OHIO	WASH.
Drying beds	9	4	6	6
Covered drying beds	0	4	1	0
Trucked as liquid	1	0	3	3
Vacuum filtered	1	2	1	1
Barged to ocean	0	2	0	0
Centrifuged	0	0	0	1
Lagooned	0	0	1	1
Composted	0	1	0	0
TOTAL	11	13	12	12

Trip Date Selection--

The first set of trips was scheduled for October and November of 1979 in order to obtain samples representative of the summer and the low flow season of the year. At the smaller plants, these samples were to be collected just prior to the operational changes that had to be made for winter conditions. The second set of trips was scheduled for the middle of February through the middle of April. This time was selected so that liquid samples would be collected during the winter months and drying bed sludge samples would be collected from drying beds that had been in winter conditions. The final set of trips was scheduled for July and August of 1980 in order to collect liquid sludges during the peak flow of the year and drying bed sludges that had been subjected to summer temperatures. The specific dates of visit are shown in Table 16.

TABLE 16. DATES DURING WHICH TREATMENT PLANTS IN MINNESOTA, NEW YORK, OHIO AND WASHINGTON WERE SAMPLED

Trip (1)			
Minnesota	October	8-12,	1979
New York	October	22-26,	1979
Ohio	November	5-9,	1979
Washington	November	26-30,	1979
Trip (2)			
Ohio	February	25-29,	1980
New York	March	10-14,	1980
Washington	March	24-28,	1980
Minnesota	April	7-11,	1980
Trip (3)			
Ohio	July	7-11,	1980
New York	July	21-25,	1980
Washington	August	11-15,	1980
Minnesota	August	25-29,	1980

Data Collection and Storage—

A sample of the data collection sheets that were used at each plant is shown in Appendix B. Data was collected on each plant, including: design flow, seasonal population served, ultimate sludge fluctuation, disposal methods, and industries served. Data was also collected about each plant at the time of the this information included: flow at time of sampling, daily high and low flow, ambient temperature, rainfall, and date of visit. Data was also collected at each site; this included: temperature, pH, redox potential or dissolved oxygen content, retention time, sludge depth and/or age for certain devices, and whether or not it was necessary to take one or twenty-liter samples.

Data collected after the samples were returned to the laboratory included: amount of sample examined in grams dry weight, number of different parasites found, total suspended and volatile solids, percent moisture content and percent volatile solids, chemical oxygen demand, pH, redox potential, total Kjedahl nitrogen, and whether or not the sludge sample was the sludge destined to leave the treatment plant.

Sample Collection—

Samples were taken with the aid of an operator to assure an understanding of the procedures of each plant. One liter samples were taken when the sludge had a high enough solid content, i.e. around 4%. In the cases of raw influent, activated sludges, and aerobic digesters, twenty-liter samples were taken and allowed to settle overnight. The next morning, the supernatant was poured off, and a one-liter sample of the sediment was taken. Most samples were collected from existing sample taps. The notable exceptions to this were Imhoff tanks. In sampling these tanks, an Eckman dredge was used to collect sediment off the bottom.

All samples were stored on ice or in a refrigerator from the time they were collected until they were processed and examined in New Orleans.

Chemical and Physical Analysis—

Laboratory sludge analyses included those for percent moisture or total suspended and volatile solids, chemical oxygen demand and total Kjeldahl nitrogen. Solids analyses were performed in accordance with Standard Methods (49). Before digestion of each liquid sludge sample, it was diluted with deionized water before COD or TKN analysis according to Standard Methods.

Parasitologic Analysis

Although work was continuing on the development of the standard technique, it was decided that the same procedures used during the study of southern plants (11) would be used for this study so that the data from both studies would be comparable. The procedures used are presented in Appendix C.

The determination of whether parasites recovered from municipal sludges were viable (alive) or nonviable (dead) was made on the basis of morphologic appearance. The morphologic criteria used to determine whether helminth eggs were viable or nonviable were similar to those used by several Japanese workers as reported by Morishita (48).

The morphologic changes that were used as criteria of dead eggs included: 1) cytolysis of egg cell (ovum) or cells (after cleavage had started); 2) vacuolation of cytoplasm of ovum; 3) formation of large refractile granules within cell; 4) cytoplasmic hyalinization; 5) shrinkage of ovum; 6) disintegration of membrane surrounding ovum; 7) caving in of egg shell. In the case of eggs containing developing larvae, viability or nonviability was determined on the basis of appearance and whether the larvae showed movement after being stimulated by intense light from the microscope lamp.

The criteria used to indicate nonviability in protozoan cysts included: 1) shrinkage of cytoplasm from the cyst wall; 2) increased granulation of cytoplasm; 3) vacuolation in cytoplasm; 4) cytolysis; 5) karyorrhexis (fragmentation of nucleus); and 6) hyalinization of cytoplasm.

Laboratory Studies on Parasite Inactivation

Five different techniques were tested for their effectiveness in inactivating parasites in municipal wastewater sludges: aerobic digestion, lime and caustic stabilization, ammonification, irradiation with Cobalt 60, and ultrasonication. These studies were carried out on sludges spiked with Ascaris suum eggs obtained from the feces of infected pigs by procedures described previously (11). Unless otherwise indicated, Ascaris eggs were recovered from sludge samples in each experiment by the technique (Procedure A) presented in Appendix C. In all cases, the viability of the Ascaris eggs recovered was determined by the cultivation method (Procedure D of Appendix C).

Technique I - Aerobic Sludge Digestion--

In the continuous digestion experiments, 15 liter aerobic sludge digesters were constructed as follows: A 45.7 cm length of 9.5 mm thick plexiglass tubing with an inner diameter of 25.4 cm was enclosed on the top and bottom with circular pieces of 9.5 mm thick plexiglass. The units were totally enclosed to retain parasite eggs for the safety of laboratory workers and for environmental control of the digester. A fan-cooled, heavy duty stirrer with two propellers on the shaft was used to obtain complete mixing. Temperature was controlled with six feet of 25.4 mm wide heating tape connected in series to a rheostat and temperature controller which was connected to a temperature probe in the digester. Aerobic conditions were maintained by sparging air from the laboratory compressed air system through 15.2 cm airstones in the digesters.

After sludge was added, digesters were allowed to stabilize for a period of at least three detention times before any experiments were undertaken. Ascaris eggs were then added to aerobic digesters having detention times of 10, 20 and 30 days at temperatures of 25° and 35°C. To determine the rate of inactivation, samples were taken for parasite analysis each time before the digesters were fed. All samples were taken in triplicate, cultured, and analyzed. At the end of the digester detention time period, the remaining sludge was used in subsequent experiments.

In addition, batch aerobic digestion experiments were conducted to test the effect of different sludge ages on the viability and recovery of Ascaris eggs from the sludge. Three small batch reactors were used in this experiment, each containing 2.5 liters of sludge. One reactor contained a mixture of primary and return activated sludge that had been digesting aerobically for 10 days prior to addition of Ascaris eggs. A second reactor contained the same mixture of primary and activated sludge, but had been digesting for 5 days prior to spiking. A third reactor contained the same mixture, but had undergone no digestion prior to spiking. The reactors consisted of plexiglass cylinders 45.7 cm high, 15.2 cm I.D. with 12.7 mm thick walls. Compressed air was supplied to the sludge by sparging through

25.4mm long aquarium air stones. Complete mixing of the sludge was accomplished by using fan-cooled stirrers with two propellers on each shaft. The units were covered to reduce the release of aerosols that could contain parasite eggs.

Technique II - Lime and Caustic Stabilization--

In order to determine the effect that caustic stabilization might have on *Ascaris* eggs, aerobically digested sludge containing *Ascaris* eggs was tested with 3.243 g NaOH per gram of suspended solids. Sludge containing caustic was then sealed in 300 ml glass BOD bottles for periods of 0, 1, 2, 5 and 10 days. Bottles were shaken daily to provide adequate mixing. Samples were taken for parasite analysis after the proper period of time had elapsed.

In order to investigate the effects of lime stabilization on *Ascaris* eggs viability and recovery, 3 small batch reactors were used. Each contained 2.5 liters of a mixture of primary and return activated sludge that had been allowed to digest aerobically for 10 days. *Ascaris* eggs were added to the digesting sludges along with 0, 100, and 1000 mg lime/g solids respectively, and allowed to aerate for another 15 days during which time samples for parasite viability and recovery were taken.

Technique III - Ammonification of Aerobically Digested Sludge--

The effects of ammonification of sludge on parasite eggs were examined using aerobically digested sludge and the surviving parasite eggs from the aerobic digester experiments. Lime or sodium hydroxide was used to increase the pH of the sludge so that the unchanged NH_3 form predominated. The effects of both ammonium sulfate and anhydrous ammonia gas were investigated.

A portion of the sludge was placed in a reaction vessel and ammonium sulfate was added or ammonia gas was bubbled through the sludge until the desired concentration of ammonia was obtained. Concentrations of ammonia were 5,000, 500 and 50.0 mg per gram suspended solids as NH_3 for ammonium sulfate additions and 1,000, 10,000, 30,000 and 40,000 mg/ℓ for anhydrous gas. When the desired ammonia concentration was obtained, the sludge was sealed in 300 ml glass stoppered BOD bottles and stored for periods of 0, 1, 2, 5, and 10 days before being opened and processed. While the ammonia was being added, care was taken to avoid temperature rise due to the addition of base or gas. Ammonia concentrations were monitored at the time of ammonia addition and at the time of sampling. In none of the experiments was loss of ammonia a problem. Ammonia concentrations were determined using an Orion probe. Bottles containing ammonified sludge were shaken once daily to insure a good mixing.

Technique IV - Irradiation by Cobalt 60—

Tulane and Sandia Laboratories conducted a collaborative study to assess the influence of irradiation by gamma irradiation on Ascaris eggs. Fresh feces from pigs naturally infected with Ascaris suum and adult female worms from the same source were collected at an abattoir in Alabama. Eggs of A. suum were collected from the feces by a process of screening and repeated washing as described previously (11). One sample of the A. suum eggs was treated to remove the outer coat of their shells by exposing them to 1% sodium hypochlorite prior to irradiation. Eggs from adult worms were obtained by removing the anterior portions of the uteri from worms and then placing them in 1% sodium hydroclorite to free the eggs and to remove the outer coat of the shell following the procedure described earlier (11).

About 10,000 washed eggs of each type (intact eggs from feces, decoated eggs from feces, and decoated eggs from worms) were added, respectively, to a one liter sample of primary sludge, adjusted to 3% sludge solids. These three samples were then labeled A, B and C and shipped to Dr. Richard Ward, Sandia Laboratories, for irradiation. At Sandia, after a thorough mixing, twenty-four 10 ml subsamples were taken from each of Samples A, B and C. Four subsamples of each type of egg-sludge mixture were exposed to each irradiation dose, i.e., 0, 50, 100, 200, 400 or 1000 Krad. The resulting 72 samples were randomly numbered and returned to our laboratory for examination. Samples were then processed as follows: Each 10 ml sample was transferred to about 100 ml of an anionic detergent (1% 7X) and mixed for 10 minutes with a magnetic stirrer. This mixture was then centrifuged, decanted and the sediment washed once with water. A solution of $ZnSO_4$ (sp. gr. 1.20) was added to the packed sediment, it was then mixed and centrifuged. The upper portion of the supernatant in each tube was decanted into a beaker, water was added to lower the specific gravity of the mixture to below 1.09. This solution was then centrifuged and the resulting sediment, after washing once in water, was placed in a few millimeters of 0.5% formalin in a small, covered plastic vial. These samples were then stored at room temperature for at least four weeks to allow embryonation of any eggs that were still alive. Then the sediment from each sample was examined microscopically and the number of eggs present and the number containing live infective-stage larvae noted.

Technique V - Ultrasonication—

The sonication system used was a Branson ultrasonic in-line liquid processor. The transducer (Part Number 904042) had 33 kHz frequency and the generator (Part Number 904040) had a maximum input energy of approximately 600 watts.

In a preliminary sonication investigation, eggs (about 8,000 eggs/ℓ) were placed in 1 liter of distilled water and circulated through the sonication unit. A flow of 0.5 liters per minute was used, and the suspension reservoir was placed in an ice bath to prevent excessive heat from building up. To obtain a 10-minute total sonication time, the suspension was circulated for 65.5 minutes. Triplicate 50 ml samples were taken at the end of this period, and they, along with the three control samples taken prior to sonication were processed and cultured. Samples were placed in culture on January 13, 1981 and read on May 8, 1981.

Unembryonated A. suum eggs recovered from the large intestine of pigs were diluted with distilled water to form a suspension of about 10,000 eggs/ℓ. This suspension was then subjected to sonication at 33 kHz and 600 watts. The sonic chamber had a capacity of 140 ml, and the suspension was circulated at a flow of 1 liter per minute. Water jacket pressure on the sonicator was kept at 14 PSI. An ice bath was employed around the suspension reservoir to keep it from excessive heat gain. Two 50 ml samples were taken at 0, 15, 30, 45 and 60 minutes, respectively, processed in the usual manner, cultured for four weeks, and then counted and checked for viability.

RESULTS

The results of the field studies and the laboratory investigations are presented separately. The types and densities of parasite eggs recovered from field samples are analyzed with regard to geographic location of plants, the types of industrial influents into plants, and the types of wastewater treatment processes utilized by the plants. The results of laboratory studies are analyzed with regard to the efficacy of each of five techniques, i.e., aerobic digestion, caustic and lime stabilization, ammonification, irradiation with Cobalt 60, and ultrasonication, in the inactivation of parasite eggs.

The parasites found in sludge samples collected from each of the 48 sewage treatment plants in the four northern states as well as the characteristics of each treatment plant and the chemical and physical characteristics of each sludge sample are presented in Appendix A. Some 20 different types of parasite eggs and cysts were detected, but many of them were identified to the genus level only. Approximately 90% of all sludge samples examined contained one or more parasites. The four most commonly found parasites were Ascaris spp., Trichuris trichiura, Trichuris vulpis, and Toxocara spp. One or more of these four parasites were found in approximately 89% of the samples examined from the four states. The number of treatment plants and the number of sludge samples in which the 16 other parasites were found in each state are presented in Table 17. The number of treatment plants in each state from which eggs of Ascaris, T. trichiura, T. vulpis and Toxocara, respectively, were found are presented in Table 18. The mean and median numbers of eggs per kg dry weight of sludge of each of these four parasites found in samples of undigested sludge, sludge from digesters, postdigestion sludge and all sludge samples from each of the four states are listed in Tables 19-22. The percentages of sludge samples positive for these four parasites are also presented in these tables and the percentages of all samples positive for these eggs in each state are, in addition, listed separately in Table 23.

TABLE 17. NUMBER OF PLANTS IN EACH NORTHERN STATE IN WHICH EGGS OR CYSTS OF PARASITES OTHER THAN ASCARIS, TRICHURIS OR TOXOCARA WERE FOUND IN ONE OR MORE SLUDGE SAMPLES

	MN (11)[1]	OH (12)	NY (13)	WA (12)	TOTAL (48)	No. positive samples
Nematode Eggs						
Capillaria spp. (striated shell)	2	8	6	4	20	75
Capillaria spp. (pitted shell)	1	4	3	1	9	15
Ascaridia-like	2	2	3	3	10	25
Trichosomides-like	0	2	2	1	5	7
Toxocaris leonina	2	0	1	0	3	7
Parascaris equorum	0	0	0	1	1	1
Spirurid: Gongylonema-like	0	1	0	0	1	1
Spirurid: Physaloptera-like	0	1	0	0	1	1
Cestode Eggs						
Hymenolepis diminuta	2	5	5	3	15	52
Diphyllobothrium latum-like	3	2	4	0	9	36
Hymenolepis nana-like	2	1	3	0	6	6
Spirometra-like	0	0	1	0	1	1
Trematode Eggs						
Schistosoma mansoni (1 egg)	0	0	1	0	1	1
Protozoa Cysts						
Entamoeba coli-like	11	9	11	8	39	50
Coccidia (oocysts)	4	2	0	2	8	9
Giardia	0	0	1	1	2	2

[1] Number of plants visited in each state.

TABLE 18. NUMBER OF TREATMENT PLANTS IN EACH NORTHERN STATE FROM WHICH EGGS OF *ASCARIS*, *TRICHURIS TRICHIURA*, *T. VULPIS* OR *TOXOCARA* WERE RECOVERED FROM ANY SLUDGE SAMPLE ACCORDING TO TIME OF YEAR (SEASON) OF SAMPLE COLLECTION

State	No. of plants examined	FALL		WINTER		SUMMER		ALL COLLECTIONS	
		Total eggs	Viable eggs	Total eggs	Viable eggs	Total eggs	Viable eggs	Total eggs	Viable eggs
				ASCARIS					
MN	11	8	7	10	8	6	6	10	10
OH	12	11	8	8	8	9	9	11	10
NY	13	7	7	7	6	7	6	9	7
WA	12	10	9	11	10	10	10	11	10
				TRICHURIS TRICHIURA					
MN	11	6	5	7	2	4	4	9	8
OH	12	9	5	5	3	4	2	11	6
NY	13	7	4	7	7	9	7	10	9
WA	12	9	6	10	9	11	10	12	12
				TRICHURIS VULPIS					
MN	11	5	4	4	2	1	1	6	4
OH	12	12	11	11	11	12	12	12	12
NY	13	12	10	10	10	11	10	13	13
WA	12	6	6	6	7	7	7	10	10
				TOXOCARA					
MN	11	11	10	10	8	11	10	11	11
OH	12	12	12	12	12	12	12	12	12
NY	13	13	12	13	13	13	13	13	13
WA	12	12	11	12	11	10	10	12	12

TABLE 19. *ASCARIS* EGGS IN SAMPLES OF UNDIGESTED SLUDGE, SLUDGE FROM DIGESTERS, AND POSTDIGESTION SLUDGE FROM WASTEWATER TREATMENT PLANTS IN FOUR NORTHERN STATES

Source or type of sludge	STATE								ALL STATES	
	MN		OH		NY		WA			
	Total[1]	Viable	Total	Viable	Total	Viable	Total	Viable	Total	Viable
Undigested										
No. of samples	44		39		43		36		162	
Mean[2]	460	310	1600	1300	930	660	4400	3700	1700	1400
% Positive	48%	48%	51%	51%	40%	33%	69%	67%	51%	49%
Geometric mean[3]	660	380	670	540	1400	970	1700	1700	940	670
Digester										
No. of samples	39		33		33		32		137	
Mean	1500	900	900	590	2000	1350	7200	5800	2800	2100
% Positive	49%	39%	55%	42%	48%	45%	75%	75%	56%	50%
Geometric mean	1100	1100	450	490	1900	1300	4700	4100	1700	1400
Postdigestion										
No. of samples	31		23		33		26		113	
Mean	330	130	400	120	300	100	4000	2600	1200	700
% Positive	68%	48%	61%	48%	33%	30%	58%	58%	54%	45%
Geometric mean	280	210	250	130	640	270	4300	1900	560	310
All Sludges										
No. of samples	114		95		109		94		412	
Mean	780	470	1100	770	1100	700	5200	4100	1900	1400
% Positive	54%	45%	55%	47%	40%	36%	68%	67%	54%	48%
Geometric mean	640	440	440	370	1500	670	2400	2000	1000	710

[1] Viable and/or nonviable eggs

[2] Number of eggs/kg dry weight of sludge

[3] Positive samples

TABLE 20. TRICHURIS TRICHIURA EGGS IN SAMPLES OF UNDIGESTED SLUDGE, SLUDGE FROM DIGESTERS, AND POSTDIGESTION SLUDGE FROM WASTEWATER TREATMENT PLANTS IN FOUR NORTHERN STATES

Source or type of sludge	STATE								ALL STATES	
	MN		OH		NY		WA			
	Total[1]	Viable	Total	Viable	Total	Viable	Total	Viable	Total	Viable
Undigested										
No. of samples	44		39		43		36		162	
Mean[2]	120	90	150	120	820	720	410	300	380	310
% Positive	34%	25%	23%	37%	44%	37%	36%	33%	35%	27%
Geometric mean[3]	240	300	390	390	830	840	430	430	500	650
Digester										
No. of samples	39		33		33		32		137	
Mean	80	20	90	80	1700	420	540	240	580	180
% Positive	21%	8%	39%	24%	55%	36%	59%	47%	42%	28%
Geometric mean	330	250	160	240	1430	1100	470	370	480	400
Postdigestion										
No. of samples	31		23		33		26		113	
Mean	40	10	20	10	270	100	290	170	160	70
% Positive	19%	10%	17%	9%	33%	21%	46%	38%	29%	19%
Geometric mean	100	120	90	90	510	180	210	190	260	130
All Sludges										
No. of samples	114		95		109		94		412	
Mean	80	40	100	80	820	440	420	240	380	200
% Positive	25%	15%	27%	16%	44%	33%	47%	39%	36%	25%
Geometric mean	260	250	170	230	830	790	480	430	440	400

[1] Viable and/or nonviable eggs

[2] Number of eggs/kg dry weight of sludge

[3] Positive samples

TABLE 21. TRICHURIS VULPIS EGGS IN SAMPLES OF UNDIGESTED SLUDGE, SLUDGE FROM DIGESTERS, AND POSTDIGESTION SLUDGE FROM WASTEWATER TREATMENT PLANTS IN FOUR NORTHERN STATES

Source or type of sludge	STATE								ALL STATES	
	MN		OH		NY		WA			
	Total[1]	Viable	Total	Viable	Total	Viable	Total	Viable	Total	Viable
Undigested										
No. of samples	44		39		43		36		162	
Mean[2]	60	50	310	300	650	640	290	290	330	320
% Positive	14%	11%	54%	54%	47%	44%	17%	17%	33%	31%
Geometric mean[3]	260	250	440	440	420	750	470	470	430	440
Digester										
No. of samples	39		33		33		32		137	
Mean	80	80	480	450	570	450	240	230	330	290
% Positive	8%	8%	70%	64%	70%	67%	53%	47%	48%	45%
Geometric mean	1100	890	360	360	760	410	330	360	460	440
Postdigestion										
No. of samples	31		23		33		26		113	
Mean	100	50	300	260	220	120	110	90	180	120
% Positive	26%	10%	74%	70%	64%	52%	27%	23%	47%	37%
Geometric mean	90	260	240	240	270	170	290	320	240	190
All Sludges										
No. of samples	114		95		109		94		412	
Mean	80	60	370	350	500	430	220	210	290	260
% Positive	15%	10%	64%	61%	59%	53%	32%	29%	42%	37%
Geometric mean	260	430	350	320	470	400	340	400	400	370

[1] Viable and/or nonviable eggs

[2] Number of eggs/kg dry weight of sludge

[3] Positive samples

TABLE 22. TOXOCARA EGGS IN SAMPLES OF UNDIGESTED SLUDGE, SLUDGE FROM DIGESTERS, AND POSTDIGESTION SLUDGE FROM WASTEWATER TREATMENT PLANTS IN FOUR NORTHERN STATES

Source or type of sludge	STATE								ALL STATES	
	MN		OH		NY		WA			
	Total[1]	Viable	Total	Viable	Total	Viable	Total	Viable	Total	Viable
Undigested										
No. of samples	44		39		43		36		162	
Mean[2]	590	540	3900	3800	1850	1800	1700	1430	2000	1900
% Positive	68%	61%	87%	85%	81%	81%	89%	89%	81%	78%
Geometric mean[3]	510	530	930	930	170	1300	1000	1000	880	870
Digester										
No. of samples	39		33		33		32		137	
Mean	1400	580	1050	660	1850	1140	1500	1100	1400	860
% Positive	85%	62%	79%	79%	91%	79%	84%	78%	85%	74%
Geometric mean	1100	830	960	960	1600	670	1100	1100	1200	740
Postdigestion										
No. of samples	31		23		33		26		113	
Mean	570	370	410	150	740	320	410	280	550	290
% Positive	81%	52%	78%	65%	67%	39%	50%	46%	69%	50%
Geometric mean	250	150	250	420	380	180	430	430	330	190
All Sludges										
No. of samples	114		95		109		94		412	
Mean	560	510	2100	1800	1500	1150	1300	1000	1400	1100
% Positive	77%	59%	82%	78%	80%	68%	71%	73%	79%	69%
Geometric mean	570	440	860	630	1400	880	1000	800	880	670

[1] Viable and/or nonviable eggs
[2] Number of eggs/kg dry weight of sludge
[3] Positive samples

TABLE 23. PERCENTAGE OF ALL SLUDGE SAMPLES IN EACH NORTHERN STATE WITH EGGS OF *ASCARIS*, *TRICHURIS TRICHIURA*, *T. VULPIS* AND *TOXOCARA*

Eggs	MN (114)[1]	OH (95)	NY (109)	WA (94)	ALL STATES
Ascaris					
Total[2]	54	55	40	68	54
Viable	45	47	36	67	48
T. trichiura					
Total	25	27	44	47	36
Viable	15	16	33	39	25
T. vulpis					
Total	15	64	59	32	42
Viable	10	61	53	29	37
Toxocara					
Total	77	82	80	77	79
Viable	59	78	68	73	69

[1] Number of samples examined

[2] Viable and/or nonviable eggs

Ascaris eggs were detected in one or more samples from 41 of the 48 treatment plants (85%) and viable eggs were detected in 37 (77%) of the plants (Table 24). *Ascaris* eggs were found in 54% of all samples examined (viable eggs in 48%) and were found equally in the three types of sludges (Table 19). *Ascaris* eggs were found in a higher percentage of the samples from Washington than from the other three states and the mean and median numbers of eggs present were higher in sludges from Washington than from the other states.

Trichuris trichiura eggs were found one or more times in 42 of the 48 plants (88%) and viable eggs were found in 35 (73%) of the plants (Table 24). *T. trichiura* eggs were found in 36% of all samples (viable eggs in 26%), but were found more frequently in sludges from digesters than in undigested or postdigestion sludges (Table 20). These eggs were found in a higher percentage of the sludge samples from New York and Washington than from Minnesota and Ohio. The numbers of eggs found were significantly higher in sludges from New York than from other states.

TABLE 24. PERCENTAGE OF PLANTS IN FOUR NORTHERN STATES WITH EGGS OF ASCARIS, TRICHURIS TRICHIURA, T. VULPIS AND TOXOCARA

Parasite	Total eggs	Viable eggs
Ascaris	85%	77%
T. trichiura	88%	73%
T. vulpis	85%	81%
Toxocara	100%	100%

Trichuris vulpis eggs were found in one or more samples from 41 of the 48 plants (85%) and viable eggs were found in 39 (81%) of the plants (Table 24). T. vulpis eggs were found in 42% of all samples (viable eggs in 37%) and were found in similar densities in the three types of sludge samples (Table 21). These eggs were found in significantly greater numbers of samples in Ohio and New York than in samples in Minnesota and Washington; however, the median numbers of eggs found in samples from each state did not differ significantly.

Toxocara was the most frequently found parasite with viable eggs being found in one or more samples from each of the 48 plants studied (Table 24). Toxocara eggs were found in 79% of all samples (viable eggs in 69%), but were found more frequently in undigested sludges and sludges from digesters (81% and 85%, respectively) than from postdigestion sludges (69%) (Table 22). The mean number of Toxocara eggs was also lower in the postdigestion than in the two other types of sludge. The percentage of samples positive for Toxocara eggs was similar in the four states, but the mean number of Toxocara eggs was considerably lower in samples from Minnesota than in samples from the other states.

Undigested Sludge—

Since earlier investigations had shown a high density of Ascaris eggs in the sludges of a southern plant treating hog processing wastes, the relationship between the presence or absence of this waste and density of parasite eggs in undigested sludges was investigated. Table 25 presents the median density of total Ascaris, T. trichiura, T. vulpis and Toxocara eggs in undigested sludges as a function of the presence or absence of 1) hog processing wastes and 2) general meat processing wastes (including hog, cattle, etc.).

TABLE 25. DENSITY OF EGGS (VIABLE AND NONVIABLE) OF ASCARIS, TRICHURIS TRICHIURA, T. VULPIS AND TOXOCARA IN POSITIVE SAMPLES OF UNDIGESTED SLUDGES FROM FOUR NORTHERN STATES IN RELATION TO THE PRESENCE OR ABSENCE OF HOG OR MEAT TREATMENT WASTES

	ASCARIS		T. TRICHIURA		T. VULPIS		TOXOCARA	
	N	Geometric[1] Mean	N	Geometric Mean	N	Geometric Mean	N	Geometric Mean
Hog wastes								
Total	83	1105	56	570	54	455	129	1015
Present	23	1285	14	670	4	600	20	730
Absent	60	1045	42	540	49	455	109	1075
Meat wastes								
Total	83	1105	56	570	53	455	129	1015
Present	49	990	27	455	21	330	52	795
Absent	34	1300	29	705	32	565	77	1190

---

[1] Antilog of the mean of the logs of positive samples expressed as number of eggs/kg dry weight.

Overall, there was no significant increase in the density of total *Ascaris* eggs (viable and nonviable combined) in undigested sludges associated with the presence of hog processing wastes. This was also true for the eggs of *T. trichiura*, *T. vulpis* and *Toxocara*. However, a significant ($p=0.002$) association between the number of samples positive for *Ascaris* eggs (viable and nonviable) and the presence of hog processing wastes was shown (Table 26). When comparisons were made using the more general category "meat treatment", no significant increases in density were noted for any of the four eggs. In fact, *Ascaris*, *T. trichiura*, and *T. vulpis* egg densities were found to be less when meat treatment wastes were present in the undigested sludges containing meat processing wastes ($p < 0.05$) than those not containing such wastes. Once again, however, a significant ($p < 0.0001$) association between the number of samples positive for *Ascaris* eggs and the presence of meat processing wastes was found (Table 26).

In order to determine if any differences in parasite density existed in undigested sludges between the four states, multiple comparisons were made of the log means of positive samples using a one-way analysis of variance and Tukey's Honestly Significantly Different Test. No significant differences in *Ascaris* egg density in undigested sludges were found between the states (Table 27) ($p=0.053$), but a potential trend was noted. However, differences in densities of viable *Ascaris* eggs were found ($p=0.0081$), with densities of viable *Ascaris* eggs being greater in Washington than in Minnesota. No other significant differences between states in *Ascaris* egg densities in undigested sludges were noted.

Significant differences between the states were also detected for total (viable and nonviable) ($p=0.002$) and viable ($p=0.015$) *T. trichiura* eggs in undigested sludges. *T. trichiura* egg (viable and nonviable) densities were greater in New York than in Minnesota.

No significant differences between the states were detected for the densities of viable ($p=0.304$) or for total (viable and nonviable) ($p=0.383$) *T. vulpis* eggs. Significant differences between the states were detected for total (viable and nonviable) ($p=0.019$) *Toxocara* egg densities. Total *Toxocara* egg densities were greater in New York undigested sludges than those from Minnesota. No other differences between the states was found. A difference between the states was observed for the densities of viable eggs of *Toxocara* ($p=0.070$), but it was not significant at the 95% confidence limits.

Table 28 presents the median densities of eggs of *Ascaris*, *T. trichiura*, *T. vulpis* and *Toxocara* in positive samples of undigested sludge as a function of season. One-way analysis of variance revealed no significant differences in the median densities between seasons for *Ascaris*, *T. trichiura*, *T. vulpis* or *Toxocara*.

Analysis of Parasite Egg Densities with Respect to Population

Scatterplots of the log of the egg density in positive undigested sludges versus the log of the population served by the treatment plant are

TABLE 26. PRESENCE OR ABSENCE OF ASCARIS EGGS (VIABLE AND NONVIABLE) IN UNDIGESTED SLUDGE SAMPLES FROM FOUR NORTHERN STATES WITH RESPECT TO PRESENCE OR ABSENCE OF HOG OR MEAT PROCESSING WASTES

	MEAT PROCESSING WASTES		HOG PROCESSING WASTES	
	Absent	Present	Absent	Present
Ascaris eggs				
Absent	65	13	72	6
Present	34	49	60	23
	x^2 = 28.721 Significance = 0.0000		x^2 = 9.59823 Significance = 0.0019	

TABLE 27. DENSITIES OF EGGS OF ASCARIS, TRICHURIS TRICHIURA, TRICHURIS VULPIS AND TOXOCARA IN POSITIVE SAMPLES OF UNDIGESTED SLUDGES FROM FOUR NORTHERN STATES

	TOTAL EGGS VIABLE AND NONVIABLE		VIABLE EGGS	
	N	Geometric Mean	N	Geometric Mean
Ascaris				
Total	83	1100	79	890
Minnesota	21	720	21	460
Ohio	20	770	20	690
New York	17	1375	14	1170
Washington	25	1820	24	1660
T. trichiura				
Total	56	570	44	650
Minnesota	15	295	11	320
Ohio	9	350	5	485
New York	19	1050	16	1100
Washington	13	700	12	680
T. Vulpis				
Total	53	455	51	460
Minnesota	6	270	5	270
Ohio	21	400	21	380
New York	20	575	19	620
Washington	6	570	6	570
Toxocara				
Total	129	1015	125	975
Minnesota	30	595	27	615
Ohio	33	1150	32	1115
New York	34	1355	34	1240
Washington	32	1075	32	985

[1] Antilog of the mean of the logs of positive samples expressed as number of eggs/kg dry weight of sludge

TABLE 28. DENSITIES OF EGGS OF *ASCARIS*, *TRICHURIS TRICHIURA*, *T. VULPIS* AND *TOXOCARA* IN POSITIVE SAMPLES OF UNDIGESTED SLUDGES FROM FOUR NORTHERN STATES AS A FUNCTION OF SEASON OF SAMPLE

	TOTAL EGGS (VIABLE AND NONVIABLE)		VIABLE EGGS	
	N	Geometric Mean[1]	N	Geometric Mean[1]
Ascaris				
Total	83	1100	79	890
Summer	25	940	23	740
Fall	29	1275	29	1030
Winter	29	1150	27	890
T. trichiura				
Total	56	570	44	650
Summer	16	440	12	430
Fall	20	790	16	950
Winter	20	570	16	600
T. vulpis				
Total	53	455	51	460
Summer	20	695	20	690
Fall	17	365	16	360
Winter	16	345	15	350
Toxocara				
Total	129	1015	125	975
Summer	41	915	39	875
Fall	40	1010	39	945
Winter	48	1115	47	1095

[1] Antilog of the mean of the logs of positive samples expressed as number of eggs/kg dry weight of sludge.

presented in Figures 3 through 10 for *Ascaris*, *T. trichiura*, *T. vulpis* and *Toxocara*. The densities of viable eggs and total eggs (viable plus nonviable) of *Ascaris* and *T. trichiura* in positive influent sludge samples were not found to be related to the size of the population served by that plant (Figures 3 through 10). The densities of viable and total eggs of *T. vulpis* and *Toxocara* in positive samples of influent sludges were found to be inversely related to the population served by the treatment plant. In both cases, decreasing densities of viable and total eggs were associated with the increasing population served by the treatment plants.

Since a significant relationship between the density of viable and total eggs of *T. vulpis* and *Toxocara* in positive samples of undigested sludges and the size of the population served by that plant was demonstrated, a step-up multiple regression analysis was used to control for changes in population size while testing the significance that the presence of meat processing wastes, state and season may have on the relationship (Tables 29 and 30).

Analysis of Parasite Densities with Respect to Population and Meat Processing Wastes—

The presence of meat processing or hog processing wastes in the undigested sludges did not have a significant effect on the density of *Ascaris* eggs in that sludge ($p > 0.25$) (Tables 29 and 30). While the presence of meat processing waste was significant in relation to the density of viable ($0.05 > p > 0.01$) *T. trichiura* eggs, a significant relationship was not seen with the density of the total eggs (viable and nonviable) of *T. trichiura* ($0.10 > p > 0.05$). In both cases, the presence of meat processing wastes was associated with a decreased density of *T. trichiura* eggs (Tables 29 and 30). The presence of meat processing wastes in undigested sludges was not significantly associated with changes in viable ($0.10 > p > 0.05$) or total ($0.25 > p > 0.10$) *T. vulpis* egg density nor was it significantly associated with changes in viable ($p > 0.25$) or total *Toxocara* egg density in undigested sludges.

Analysis of Parasite Egg Densities with Respect to Population, Meat Processing and State—

The densities of both viable ($0.05 > p > 0.01$) and total ($0.05 > p > 0.01$) *Ascaris* eggs was found to vary with the state sampled (Tables 29 and 30). Positive samples of undigested sludges in New York and Washington contained greater densities of viable *Ascaris* eggs than did those from Minnesota ($p < 0.05$). The densities of viable *Ascaris* eggs in Ohio were not significantly different from those in Minnesota. Undigested sludges from Washington contained greater densities of total *Ascaris* eggs than did those from Minnesota ($p < 0.05$). No other differences in total *Ascaris* eggs densities in regard to other states were noted.

The densities of both viable ($p < 0.001$) and total ($p.05 < p < 0.01$) *T. trichiura* eggs in undigested sludges were found to vary from state to state. Both viable and total egg densities were found to be greater in New York and Washington than in Minnesota. No other differences were noted.

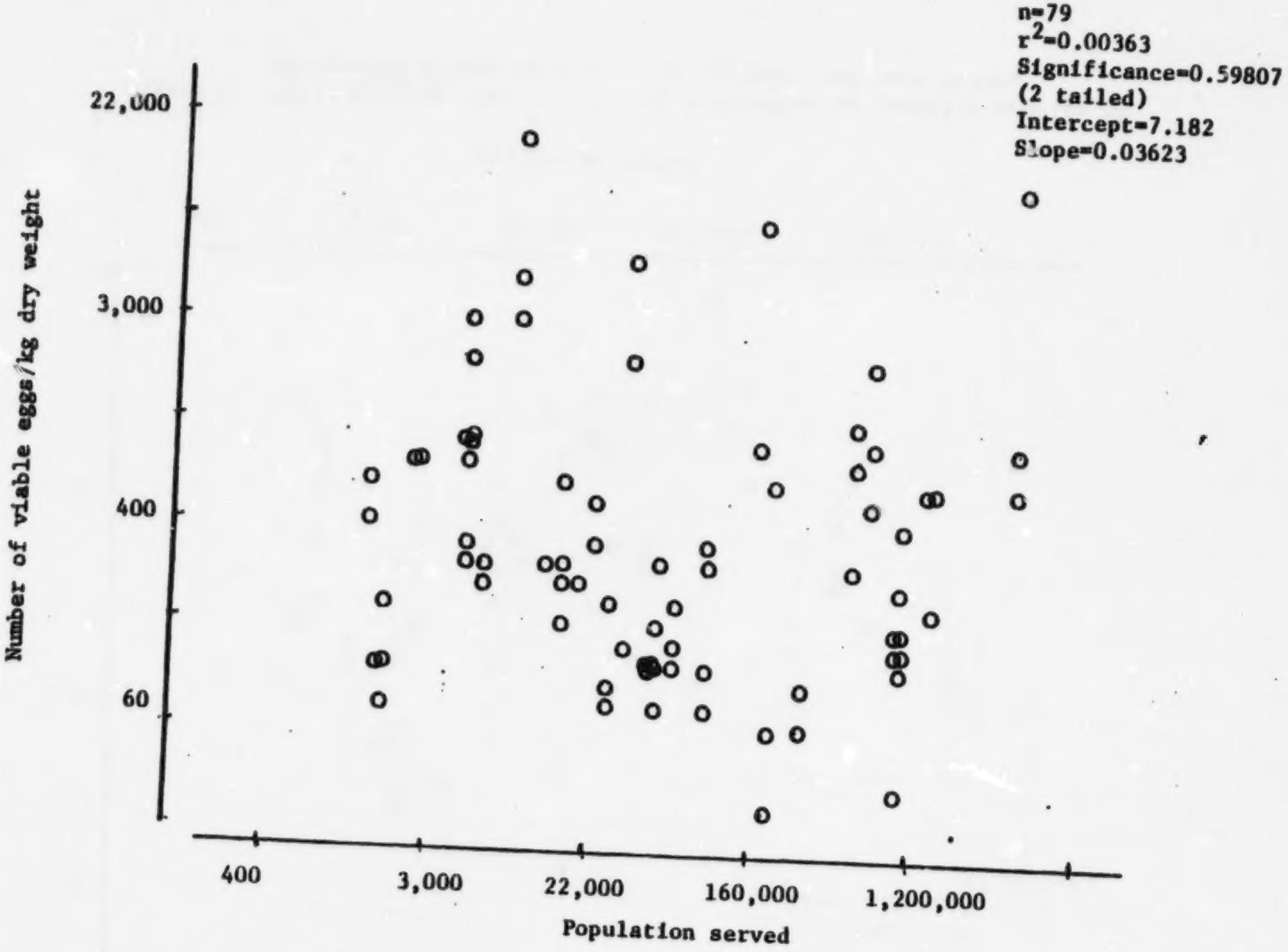


Figure 3: Viable Ascaris in positive samples of undigested sludge vs. population served; northern states.

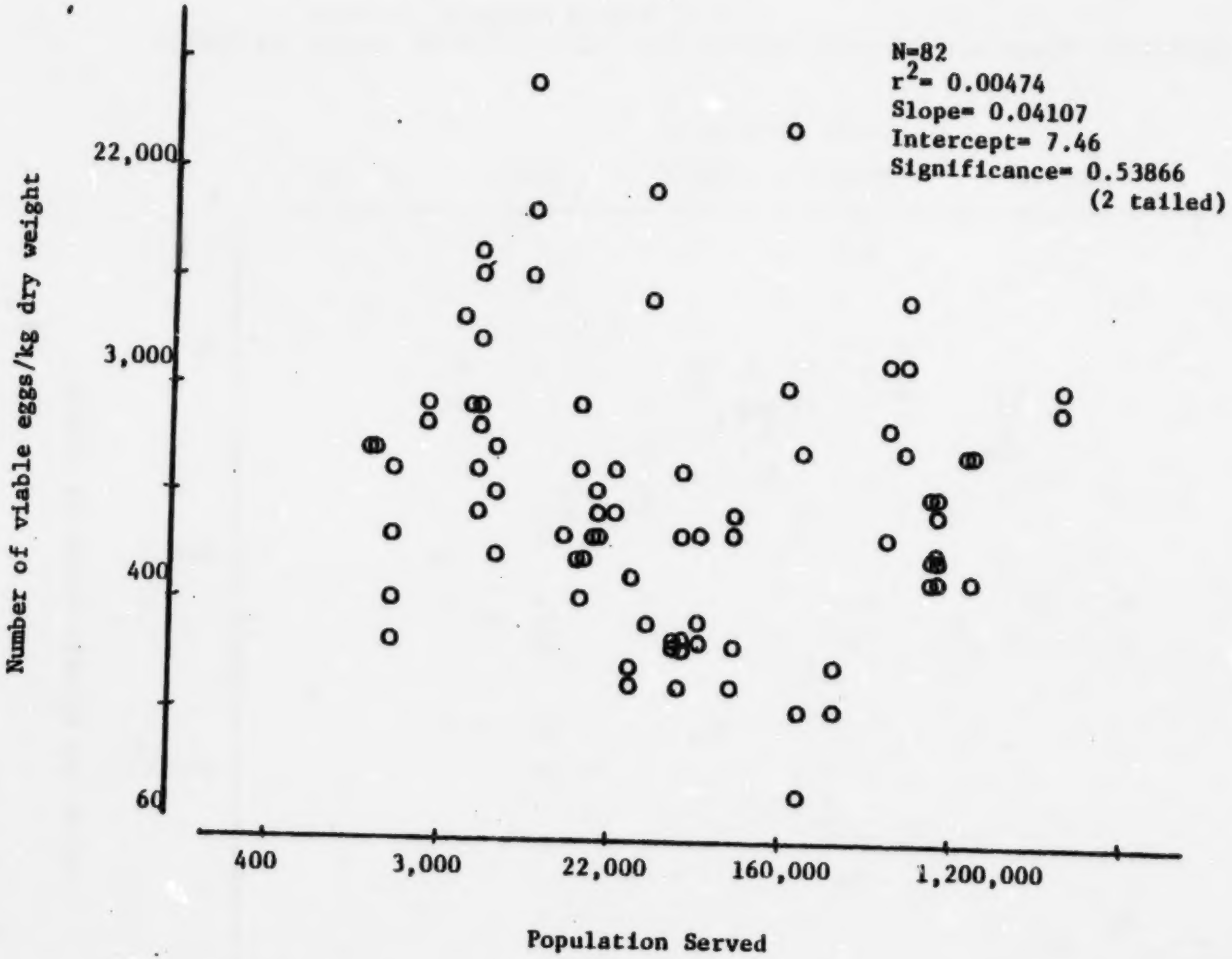


Figure 4. Total *Ascaris* eggs (viable and nonviable) in positive samples of undigested sludge vs. population served: northern states.

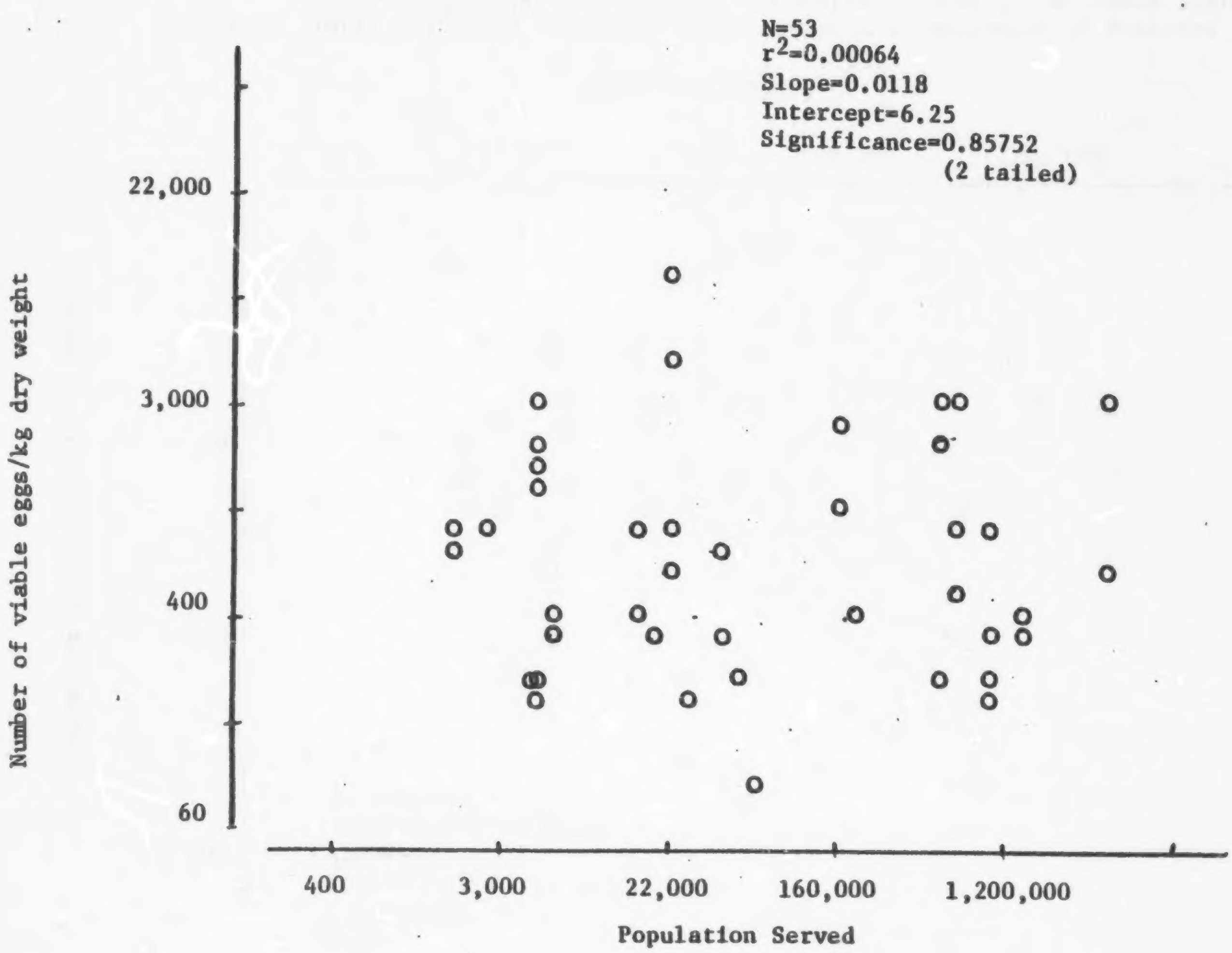


Figure 5. Viable Trichuris trichiura eggs in positive samples of undigested sludge vs. population served: northern states.

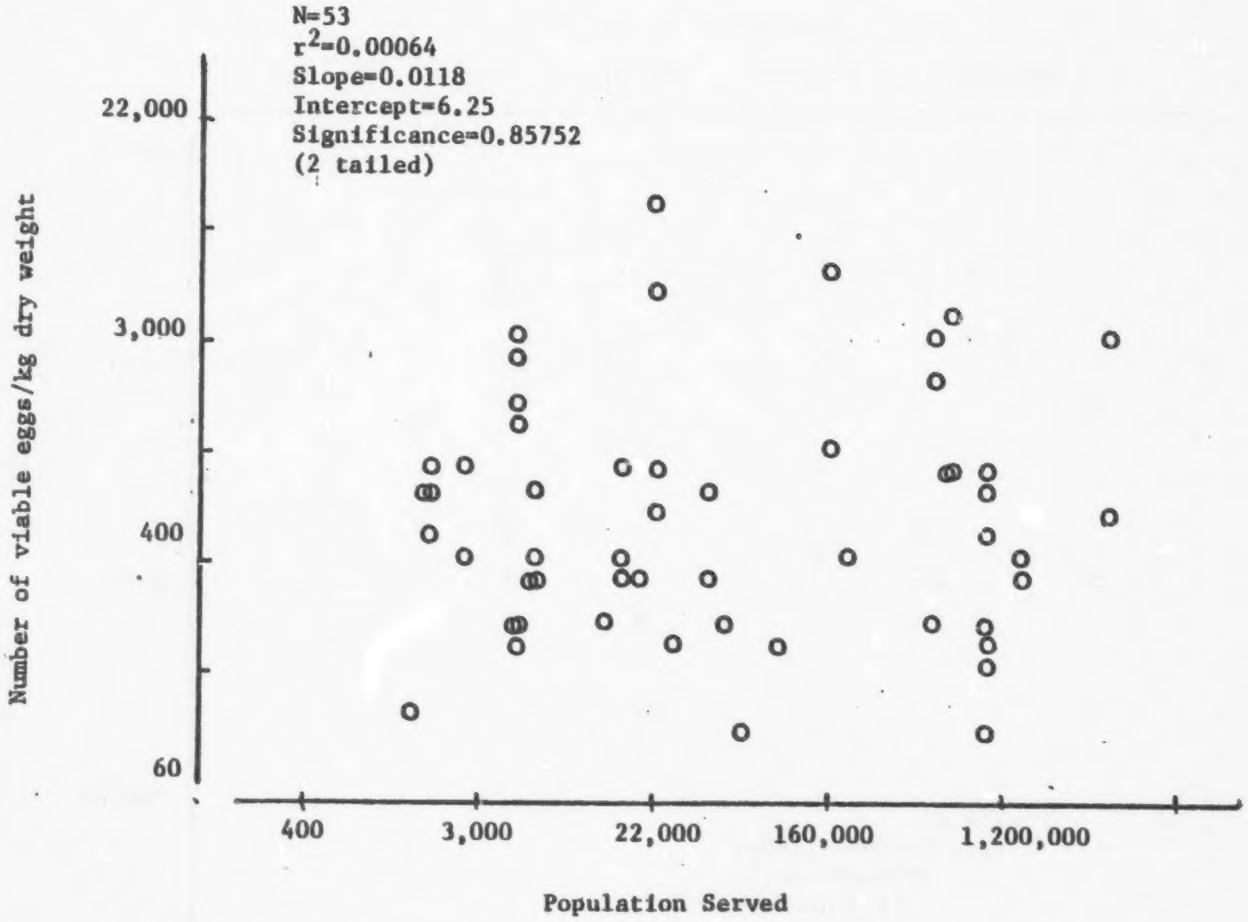


Figure 6: Total *Trichuris trichiura* eggs (viable and nonviable) in positive samples of undigested sludges vs. population served: northern states.

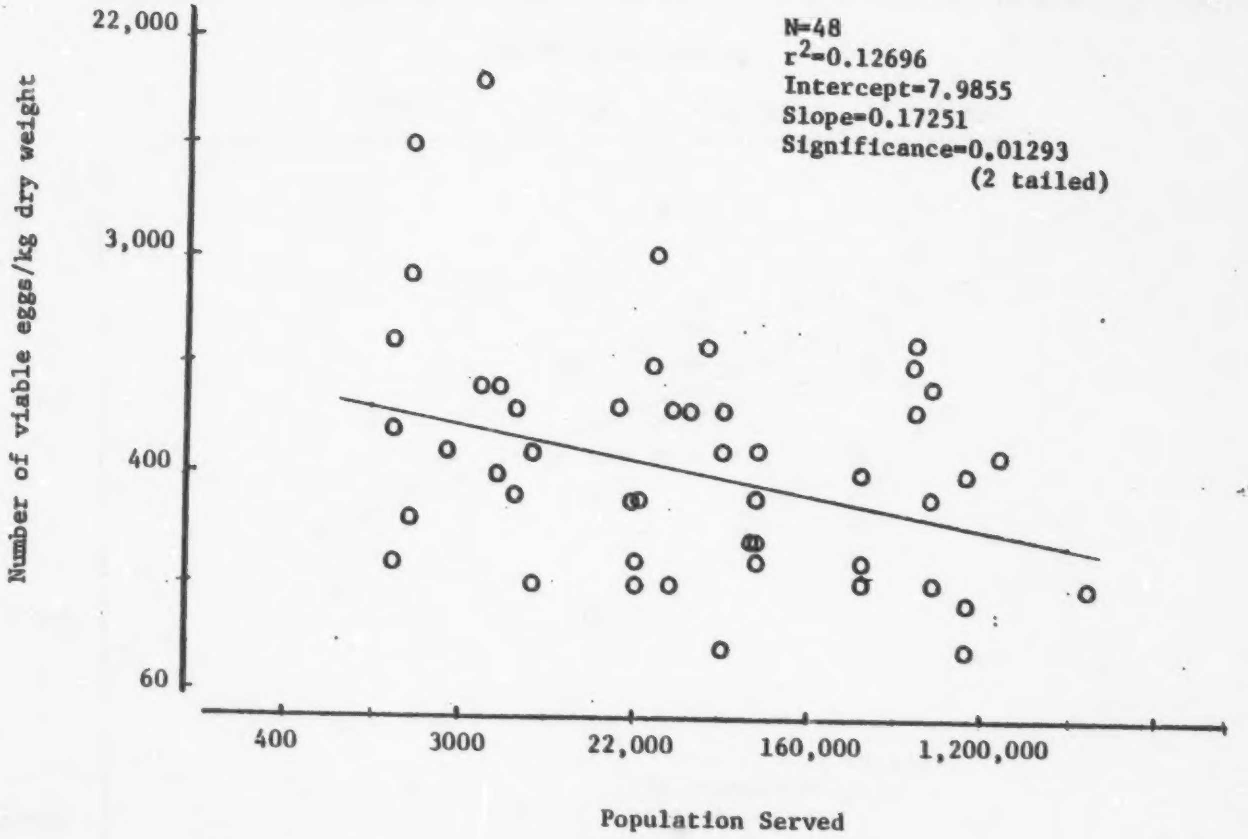


Figure 7. Viable Trichuris vulpis eggs in positive samples of undigested sludge vs.population served: northern states.

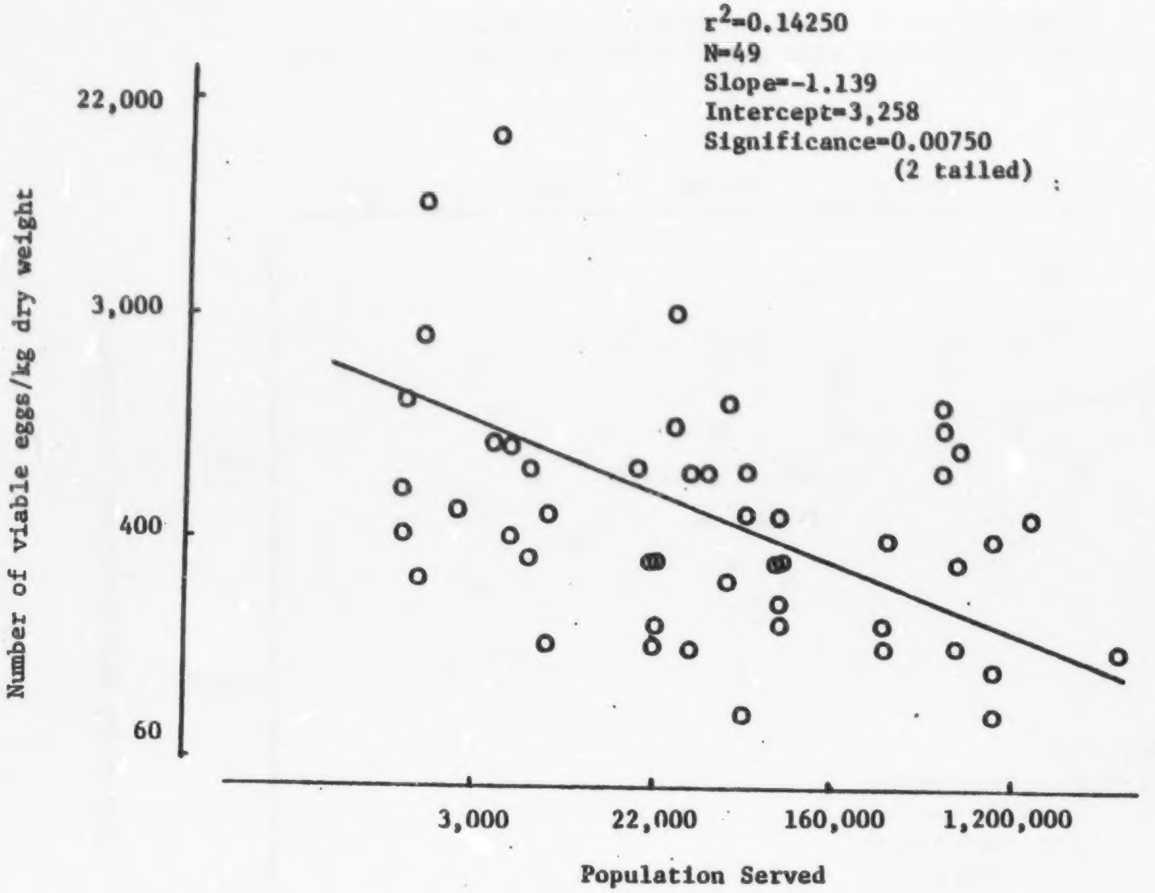


Figure 8: Total *Trichuris vulpis* eggs (viable and nonviable) in positive samples of undigested sludge vs. population served: northern states.

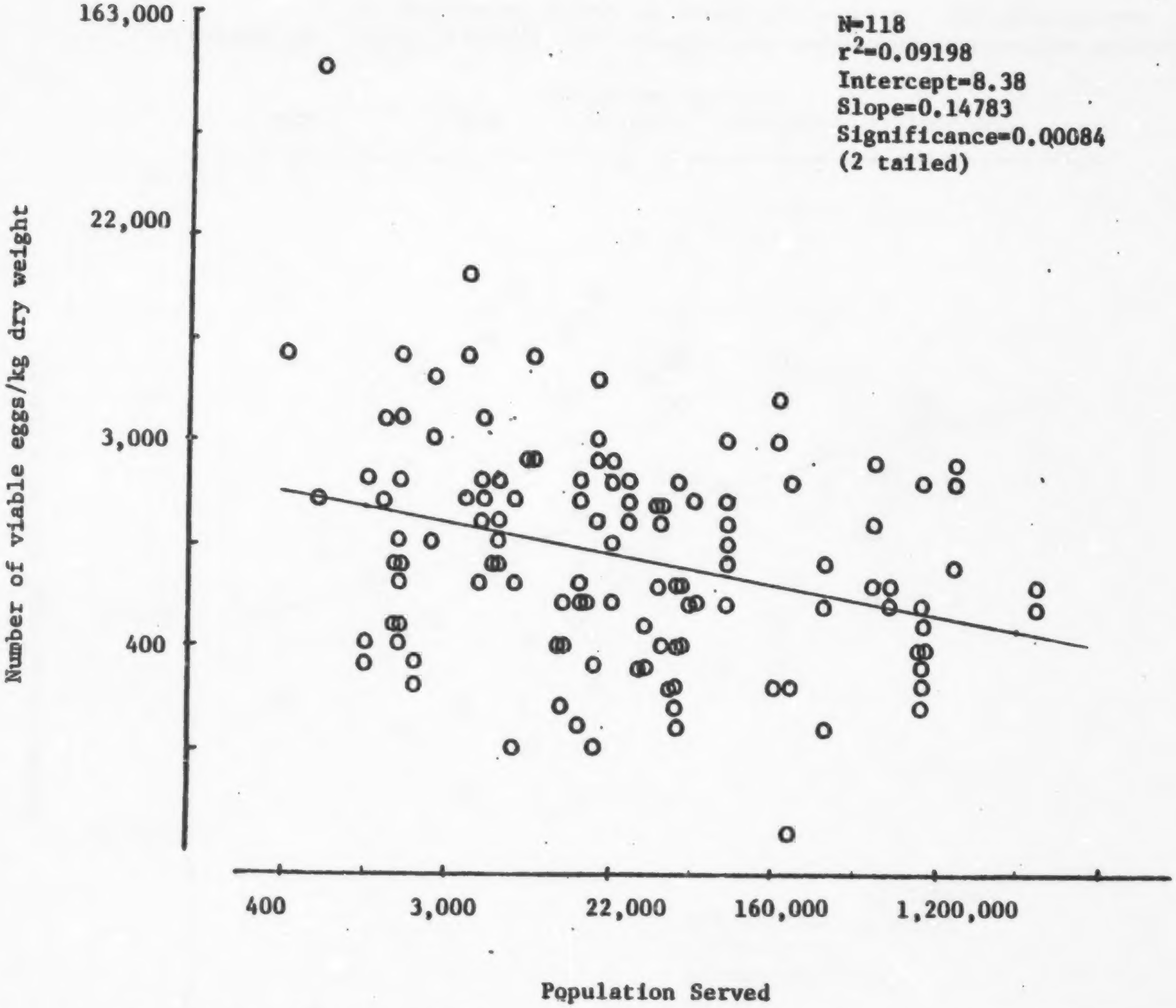


Figure 9: Viable _Toxocara_ eggs in positive samples of undigested sludge vs. population served: northern states.

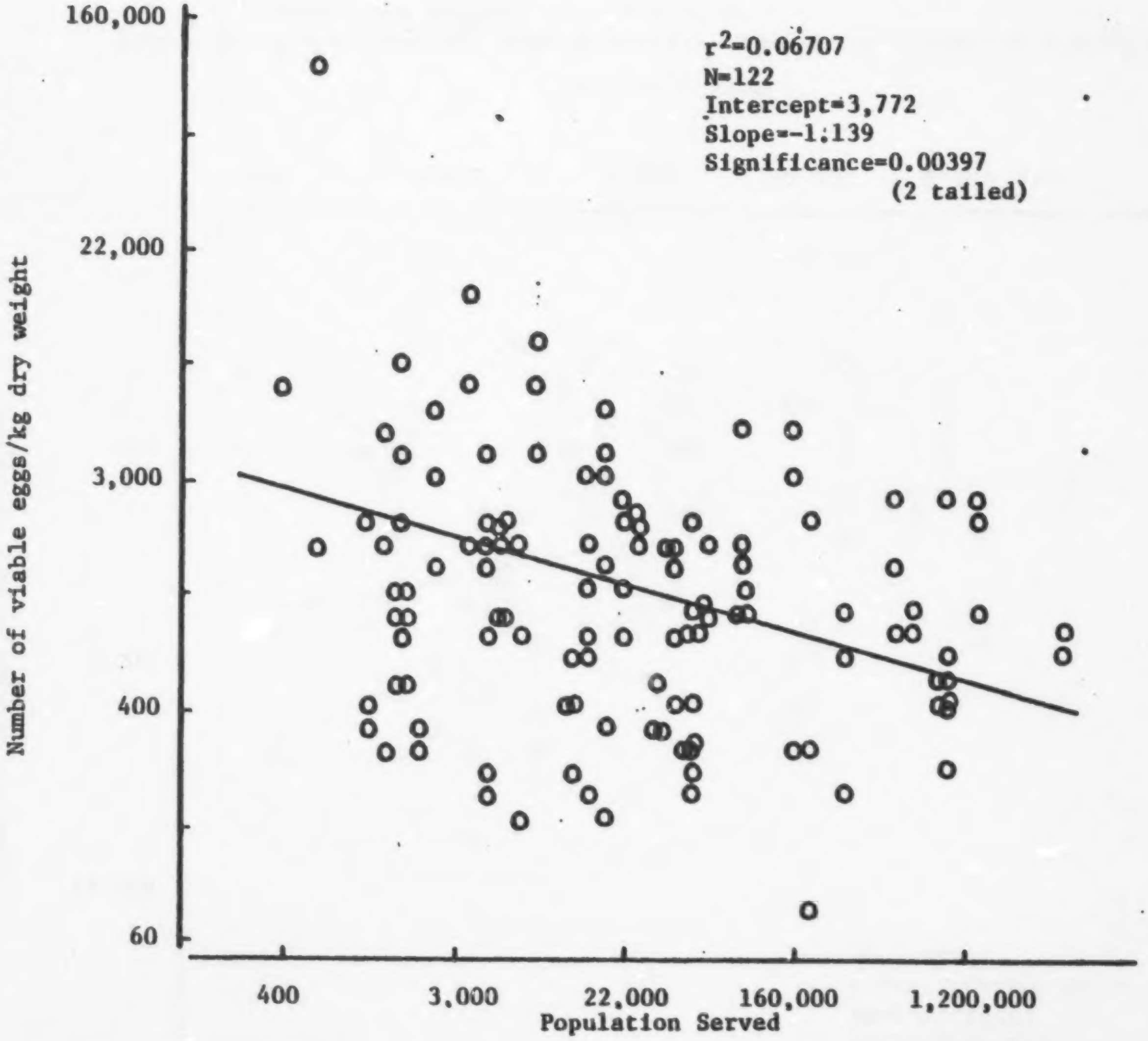


Figure 10. Total Toxocara eggs (viable and nonviable) in positive samples of undigested sludge vs. population served: northern states.

TABLE 29. ANALYSIS OF THE RELATIONSHIP OF POPULATION, WASTES, STATE AND SEASON TO THE DENSITY OF VIABLE EGGS OF *ASCARIS*, *TRICHURIS TRICHIURA*, *TRICHURIS VULPIS* AND *TOXOCARA* IN POSITIVE SAMPLES OF UNDIGESTED SLUDGE FROM FOUR NORTHERN STATES[1]

	No. of samples	Population served	Meat processing wastes	State	Season
Ascaris	79	$p>0.25$	$p>0.25$	$0.05>p>0.01$	$p>0.25$
T. trichiura	41	$p>0.25$	$0.05>p>0.01$	$0.05>p>0.01$	$0.05>p>0.01$
T. vulpis	48	$0.05>p>0.01$	$0.10>p>0.05$	$p>0.25$	$0.10>p>0.05$
Toxocara	118	$p<0.001$	$p>0.25$	$0.05>p>0.05$	$p>0.25$

TABLE 30. ANALYSIS OF THE RELATIONSHIP OF POPULATION, WASTES, STATE AND SEASON TO THE DENSITY OF EGGS OF *ASCARIS*, *TRICHURIS TRICHIURA*, *TRICHURIS VULPIS* AND *TOXOCARA* (VIABLE AND NONVIABLE) IN POSITIVE SAMPLES OF UNDIGESTED SLUDGES OF FOUR NORTHERN STATES[1]

	No. of samples	Population served	Meat processing wastes	State	Season
Ascaris	82	$p>0.25$	$p>0.25$	$0.05>p>0.01$	$p>0.25$
T. trichiura	53	$p>0.25$	$0.10>p>0.05$	$p<0.001$	$0.25>p>0.10$
T. vulpis	49	$0.01>p>0.001$	$0.25>p>0.10$	$p>0.25$	$0.01>p>0.05$
Toxocara	122	$0.01>p>0.001$	$p>0.25$	$0.05>p>0.01$	$p>0.25$

[1] This is the probability that the listed parameter is by chance associated with the density level of parasite eggs. If the parameter was observed to be significant ($p \leq 0.05$), it was taken into account in the testing of subsequent parameters.

The densities of viable ($p > 0.25$) and total ($p > 0.25$) *T. vulpis* eggs in undigested sludges were not found to vary significantly between states.

The densities of viable ($0.005 > p > 0.001$) and total ($0.05 > p > 0.01$) *Toxocara* eggs were found to vary significantly between states. Viable and total *Toxocara* eggs were found in greater densities from undigested samples from Ohio and New York than from Minnesota. Sludges from Washington also had greater densities of total *Toxocara* eggs than did those from Minnesota. No other state differences were found.

No seasonal differences in the densities of viable ($p > 0.25$) or total ($p > 0.25$) *Ascaris* eggs were noted (Tables 29 and 30). There were seasonal differences in viable *T. trichiura* densities ($0.05 > p$ 0.01), with fewer viable *T. trichiura* eggs per kilogram undigested sludge being found in the summer and winter than in the fall, although no such differences were noted on the densities of viable ($0.10 > p > 0.05$) or total ($0.10 > p > 0.05$) *T. vulpis* eggs or viable ($p > 0.25$) or total ($p > 0.25$) *Toxocara* egg densities.

Southern Undigested Sludges--

Analysis of Parasite Egg Densities with Respect to Population--

No significant relationship between population and parasite egg densities in undigested sludges was demonstrated for viable or total *Ascaris*, *T. vulpis* and *Toxocara* eggs. Although the density of viable *T. trichiura* eggs was found to vary inversely with the size of the population served ($p = 0.046$), the density of total *T. trichiura* eggs did not exhibit such a relationship (Figures 11 and 12).

As noted earlier, the one plant in the south with hog processing wastes contained very high densities of viable and total *Ascaris* eggs in its sludges. When the general category of meat processing wastes was used, however, the egg densities of total *Ascaris*, *T. trichiura*, *T. vulpis* and *Toxocara* were not greater than those in sludges with no meat wastes. In fact, egg densities were generally greater when meat processing wastes were not present (Table 31)

Although egg densities in southern undigested sludges in general were not found to vary with the population served by the plant, it was decided to control for population since it had been important in the northern states. These relationships are shown in Tables 32 and 33.

A multiple regression analysis was undertaken, similar to that used for northern undigested sludges, controlling for the population served by the plant and testing for significant effects of meat processing waste, region of sample, and season of sample on the relationship.

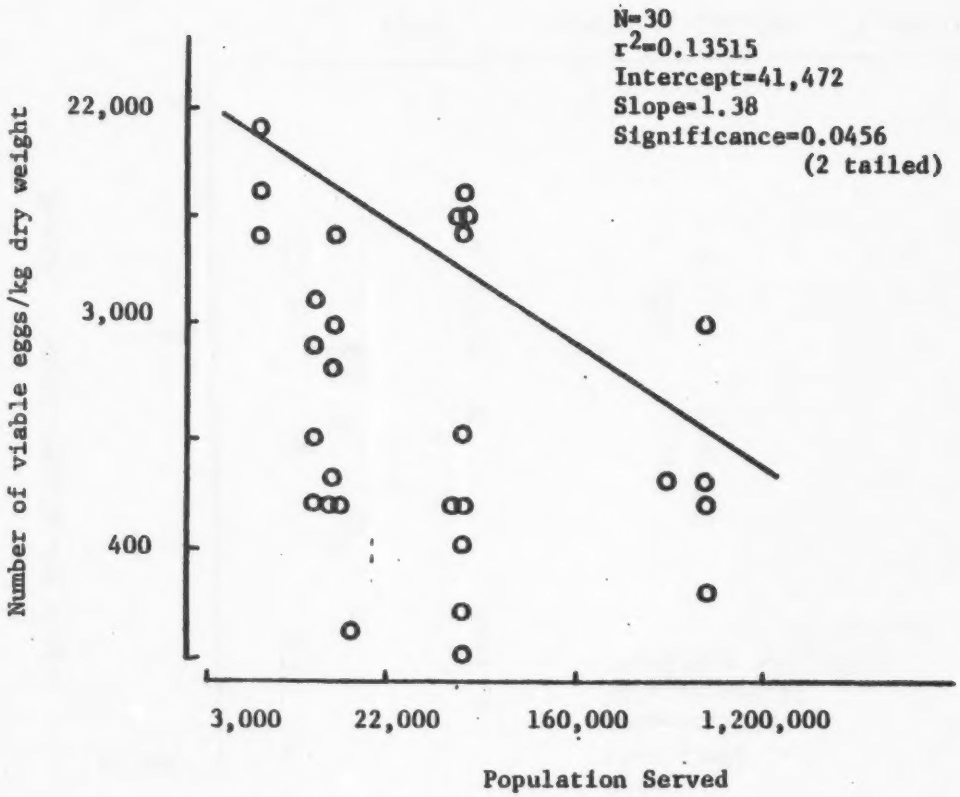


Figure 11. Viable Trichuris trichiura eggs in positive samples of undigested sludge vs. population served: southern states.

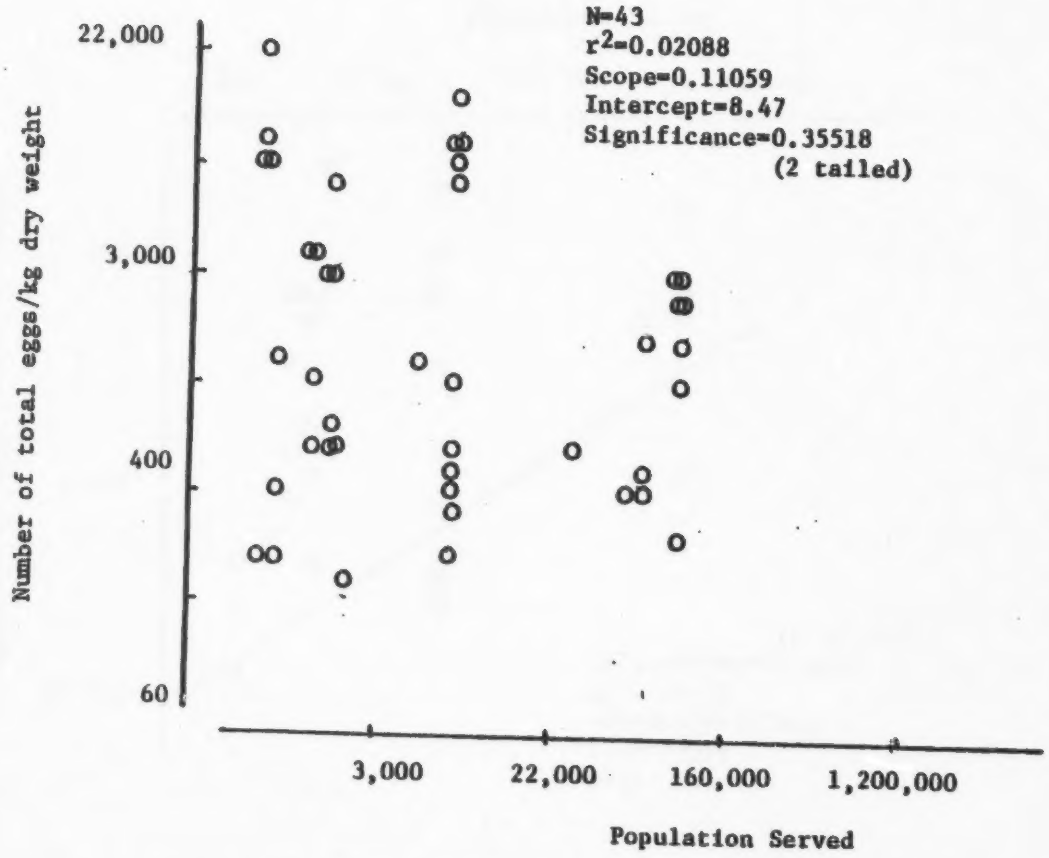


Figure 12. Total Trichuris trichiura eggs (viable and nonviable) in positive samples of undigested sludge: southern states.

TABLE 31. DENSITIES OF TOTAL *ASCARIS*, *TRICHURIS TRICHIURA*, *T. VULPIS* AND *TOXOCARA* EGGS IN POSITIVE SAMPLES OF UNDIGESTED SLUDGES FROM FIVE SOUTHERN STATES IN RELATION TO THE PRESENCE OR ABSENCE OF MEAT PROCESSING WASTES

Meat wastes	*ASCARIS*		*T. TRICHIURA*		*T. VULPIS*		*TOXOCARA*	
	N[1]	Geometric Mean[2]	N	Geometric mean	N	Geometric mean	N	Geometric mean
Total	30	3830	46	1275	64	640	87	1065
Present	20	3830	30	1260	33	620	46	810
Absent	10	3830	16	1310	31	660	41	1440

[1] Number of samples

[2] Antilog of the mean of the logs of positive samples expressed as number of eggs/kg dry weight

TABLE 32. ANALYSIS OF THE RELATIONSHIP OF POPULATION, WASTES, REGION AND SEASON TO THE DENSITY OF TOTAL EGGS OF *ASCARIS*, *TRICHURIS TRICHIURA*, *T. VULPIS* AND *TOXOCARA* IN POSITIVE SAMPLES OF UNDIGESTED SLUDGE FROM FOUR SOUTHERN REGIONS[1]

Parasite	No. of samples	Population served	Meat processing wastes	Region	Season
Ascaris[2]	74	$p>0.25$	$p>0.25$	$0.25>p>0.10$	$p>0.25$
T. trichiura	43	$p>0.25$	$p>0.25$	$0.05>p>0.01$	$p>0.25$
T. vulpis	49	$p>0.25$	$p>0.25$	$p>0.25$	$0.10>p>0.10$
Toxocara	69	$0.10>p>0.25$	$0.01>p>0.001$	$p>0.25$	$0.25>p>0.10$

[1] This is the probability that the listed parameter is by chance associated with the density level of parasite eggs. If the parameter was observed to be significant ($p \leq 0.05$), it was taken into account in the testing of subsequent parameters.

[2] Does not include plant 507.

TABLE 33. ANALYSIS OF THE RELATIONSHIP OF POPULATION, WASTES, REGION AND SEASON TO THE DENSITY OF VIABLE EGGS OF *ASCARIS*, *TRICHURIS TRICHIURA*, *T. VULPIS* AND *TOXOCARA* IN POSITIVE SAMPLES OF UNDIGESTED SLUDGE FROM FOUR SOUTHERN REGIONS[1]

Parasite	No. of samples	Population served	Meat processing wastes	Region	Season
Ascaris[2]	74	$p>0.25$	$p>0.25$	$0.25>p>0.10$	$0.25>p>0.10$
T. trichiura	30	$0.05>p>0.01$	$p>0.25$	$p<0.001$	$p>0.25$
T. vulpis	48	$p>0.25$	$p>0.25$	$p>0.25$	$p>0.25$
Toxocara	67	$p>0.25$	$0.05>p>0.01$	$p>0.25$	$0.1>p>0.05$

---

[1] This is the probability that the listed parameter is by chance associated with the density level of parasite eggs. If the parameter was observed to be significant ($p \leq 0.05$), it was taken into account in the testing of subsequent parameters.

[2] Does not include plant 507.

Analysis of Parasite Egg Densities with Respect to Population and Meat Processing Wastes--

No significant effect due to the presence of meat processing wastes was noted in the densities of viable and total *Ascaris*, *T. trichiura*, and *T. vulpis* eggs in undigested sludges. Fewer viable ($0.05 > p$ 0.01) and total ($0.01 > p > 0.001$) *Toxocara* eggs were found when meat processing wastes were present in undigested sludges.

Analysis of Parasite Egg Densities with Respect to Population, Meat Processing and Region--

No significant differences in viable ($0.25 > p > 0.10$) and total ($0.25 > p > 0.10$) *Ascaris* egg densities in undigested sludges were found between the regions. Viable ($p < 0.0001$) and total ($0.05 > p > 0.01$) *T. trichiura* egg densities were found to vary with region of sample, however. Undigested sludges in Region II had greater viable and total *T. trichiura* egg densities than did those in Region I (see map in Appendix E). No significant differences in viable or total *T. vulpis* ($p > 0.25$) densities were noted between the regions.

Analysis of Parasite Egg Densities with Respect to Population, Meat Processing and Season--

No significant differences in viable or total egg densities was found between seasons for *Ascaris*, *T. trichiura*, *T. vulpis* or *Toxocara*.

Comparison of North and South Undigested Sludges—

In order to determine if differences existed between egg densities in the north and south, multiple regression analysis was used, in much the same manner as before (Tables 34 and 35). While the population served by the treatment plant was not significant for viable or total eggs of Ascaris ($p > 0.25$) and T. trichiura ($p > 0.25$) it was significant for viable and total egg densities of T. vulpis ($0.01 > p > 0.001$). Decreasing densities of viable and total T. vulpis eggs were significantly associated with the increasing population served by the treatment plant. This was also found to be the case with viable ($p < 0.001$) and total ($0.01 > p > 0.001$) Toxocara egg densities.

The effect of meat processing wastes was not found to be significant for viable or total Ascaris ($p > 0.25$) T. trichiura ($p > 0.25$) or T. vulpis ($p > 0.25$) egg densities. The presence of meat processing wastes was significantly associated with decreases in total Toxocara egg density ($0.01 > p > 0.001$) although not with viable Toxocara eggs ($0.10 > p > 0.05$). There were significant differences in viable and total ($p < 0.001$) Ascaris egg densities in undigested sludges, with the southern sludges containing greater densities of eggs. More viable ($0.05 < p < 0.01$) and total ($p < 0.001$) T. trichiura and total ($0.05 > p > 0.01$) T. vulpis eggs were found in southern undigested sludges, but not viable ($0.10 > p > 0.05$) T. vulpis eggs. No significant differences between egg densities in undigested sludges between the north and south could be demonstrated for viable or total Toxocara ($p > 0.25$) eggs.

Northern Digested Sludges—

Table 36 presents the median densities of the eggs of Ascaris, T. trichiura, T. vulpis and Toxocara eggs in positive samples of aerobic, anaerobic, and Imhoff digestion sludge as a function of the presence or absence or meat or hog processing wastes.

No significant differences in the densities of the eggs of Ascaris, T. trichiura, T. vulpis or Toxocara were found to be associated with the presence of meat processing wastes. The presence of hog processing wastes was associated with a significant increase in the densities of Ascaris eggs (viable and nonviable combined) in digestion sludges ($p < 0.05$) although this was not the case for viable Ascaris eggs alone. The presence of hog processing wastes was not associated with significant changes in the densities of T. trichiura, T. vulpis or Toxocara eggs in digested sludges.

Table 37 presents the median densities of eggs of Ascaris, T. trichiura, T. vulpis and Toxocara in positive samples of anaerobic, aerobic and Imhoff digestion sludges.

A one-way analysis of variance was used to test for differences in egg densities between states for viable eggs and for the total number of eggs (viable and nonviable combined) of Ascaris, T. trichiura, T. vulpis and Toxocara. Significant differences between states were found for densities

TABLE 34. ANALYSIS OF THE RELATIONSHIP OF POPULATION, WASTES AND REGION TO THE DENSITY OF TOTAL EGGS OF ASCARIS, TRICHURIS TRICHIURA, T. VULPIS AND TOXOCARA IN POSITIVE SAMPLES OF UNDIGESTED SLUDGES FOR THE NORTH-SOUTH COMBINED DATA SET[1]

Parasite	No. of samples	Population served	Meat processing wastes	Region or state
Ascaris[2]	156	$p>0.25$	$0.25>p>0.10$	$p<0.001$
T. trichiura	96	$p>0.25$	$p>0.25$	$p<0.001$
T. vulpis	98	$0.01>p>0.001$	$p>0.25$	$0.05>p>0.01$
Toxocara	191	$0.01>p>0.001$	$0.01>p>0.001$	$p>0.25$

TABLE 35. ANALYSIS OF THE RELATIONSHIP OF POPULATION, WASTES AND REGION TO THE DENSITIES OF VIABLE EGGS OF ASCARIS, TRICHURIS TRICHIURA, T. VULPIS AND TOXOCARA IN POSITIVE SAMPLES OF UNDIGESTED SLUDGE FOR THE NORTH-SOUTH COMBINED DATA SET[1]

Parasite	No. of samples	Population served	Meat processing wastes	Region or state
Ascaris[2]	153	$p>0.25$	$p>0.25$	$p<0.001$
T. trichiura	71	$p>0.25$	$p>0.25$	$0.01>p>0.001$
T. vulpis	96	$0.01>p>0.001$	$p>0.25$	$0.10>p>0.05$
Toxocara	185	$p>0.25$	$0.10>p>0.05$	$p>0.25$

---

[1] This is the probability that the listed parameter is by chance associated with the density level of parasite eggs. If the parameter was observed to be significant ($p \leq 0.05$), it was taken into account in the testing of subsequent parameters.

[2] Does not include Plant #507.

TABLE 36. DENSITIES OF TOTAL EGGS OF *ASCARIS*, *TRICHURIS TRICHIURA*, *T. VULPIS* AND *TOXOCARA* IN POSITIVE SAMPLES OF AEROBIC, ANAEROBIC AND IMHOFF DIGESTION SLUDGES IN NORTHERN STATES IN RELATION TO THE PRESENCE OR ABSENCE OF MEAT OR HOG PROCESSING WASTES

	ASCARIS		T. TRICHIURA		T. VULPIS		TOXOCARA	
Processing wastes	N[1]	Geometric mean[2]	N	Geometric mean	N	Geometric mean	N	Geometric mean
Hog wastes								
Total	69	1865	49	475	58	430	106	1165
Present	18	3430	10	555	10	430	17	1075
Absent	51	1495	39	455	48	430	89	1175
Meat wastes								
Total	69	1865	49	475	58	430	106	1165
Present	33	2240	20	420	20	320	31	910
Absent	36	1565	29	510	38	510	75	1290

---

[1] No. of samples

[2] Antilog of the mean of the logs of positive samples expressed in number of eggs/kg dry weight.

TABLE 37. DENSITIES OF ASCARIS, TRICHURIS TRICHIURA, T. VULPIS AND TOXOCARA EGGS IN POSITIVE SAMPLES OF AEROBIC, ANAEROBIC AND IMHOFF DIGESTION SLUDGES FROM FOUR NORTHERN STATES

		TOTAL EGGS		VIABLE EGGS	
Parasite	State	N	Geometric mean[1]	N	Geometric mean
Ascaris	Total	69	1860	61	1695
	MN	19	1645	15	1435
	OH	14	670	11	750
	NY	13	1625	12	1150
	WA	23	4125	23	3410
T. trichiura	Total	49	475	31	425
	MN	8	325	3	180
	OH	11	475	6	310
	NY	12	1235	7	960
	WA	18	540	15	390
T. vulpis	Total	58	430	53	440
	MN	3	1175	3	1010
	OH	21	360	19	390
	NY	18	555	17	475
	WA	16	350	14	405
Toxocara	Total	106	1165	92	725
	MN	33	1135	24	695
	OH	23	990	23	575
	NY	25	1420	22	730
	WA	25	1145	23	960

---

[1] Antilog of the mean of the logs of positive samples expressed as number of eggs/kg dry weight.

of total eggs ($p=0.005$) and viable eggs ($p=0.020$) of *Ascaris*. Application of Tukey's HSD test indicated that higher densities of total and viable *Ascaris* eggs were found in digestion sludges in Washington than in Ohio and Minnesota. No statistical differences were noted for *Ascaris* egg densities between the other states.

Significant differences in densities of total eggs (viable and nonviable) ($p=0.0005$) and viable eggs only ($p=0.010$) of *T. trichiura* in digestion sludges were also found between some states. Digested sludges in New York were found to contain higher densities of *T. trichiura* eggs (both total and viable only) than did those from Minnesota and Ohio. Digested sludges from Washington contained greater densities of total eggs (viable plus nonviable) of *T. trichiura* than did those from Ohio. No significant differences in *T. trichiura* egg densities in digested sludges between other states were noted. No significant differences in the densities of *T. vulpis* or *Toxocara* eggs in digested sludges from the different states were noted. However, there was a low number of positive samples for Minnesota as compared to the other states for *T. vulpis*.

Table 38 presents the median densities of the eggs of *Ascaris*, *T. trichiura*, *T. vulpis* and *Toxocara* in positive samples of anaerobic, aerobic and Imhoff digestion sludges as a function of season of sample. Analysis of variance revealed no differences in egg densities between the seasons for any parasite in digester sludges.

Table 39 presents the median densities of the eggs *Ascaris*, *T. trichiura*, *T. vulpis* and *Toxocara* as a function of digester type. As seen from the tables, the major proportion of samples are from anaerobic digesters.

Analysis of Parasite Egg Densities with Respect to Population, Meat Processing, State, Digestion Process and Season--

Scatterplots of viable and total egg densities in positive samples of aerobic, anaerobic and Imhoff digestion sludges vs the log of the population served by the plant are presented in Figures 13 through 20 for *Ascaris*, *T. trichiura*, *T. vulpis* and *Toxocara* eggs. The statistical analysis of this data is illustrated in Tables 40 and 41. A multiple regression analysis was undertaken, similar to that used for northern undigested sludges, controlling for the population served by the plant and testing for significant effects of meat processing waste, region of sample, and season of sample on the relationship.

The densities of viable ($p < 0.01$) and total ($p < 0.02$) *Ascaris* eggs were found to increase with increasing population size (Figures 13 and 14). This was also found to be the case with the eggs of *T. trichiura* ($p < 0.001$) (Figures 15 and 16). The density of total *T. vulpis* eggs also increased with increasing population size (Figure 18), but densities of viable *T. vulpis* eggs in digester sludges did not (Figure 17). The densities of viable and total *Toxocara* eggs were not found to be significantly related to the population served by the treatment plant (Figures 19 and 20).

TABLE 38. DENSITIES OF EGGS OF ASCARIS, TRICHURIS TRICHIURA, T. VULPIS AND TOXOCARA IN POSITIVE SAMPLES OF AEROBIC, ANAEROBIC AND IMHOFF DIGESTION SLUDGES FROM FOUR NORTHERN STATES AS A FUNCTION OF SEASON OF SAMPLE COLLECTION

	VIABLE EGGS		TOTAL EGGS (VIABLE AND NONVIABLE)	
	N	Geometric Mean[1]	N	Geometric Mean[1]
Ascaris				
Total	61	1695	69	1866
Summer	17	2260	19	2475
Fall	17	1495	21	1240
Winter	27	1530	29	2065
T. trichiura				
Total	31	424	49	475
Summer	10	340	15	485
Fall	9	510	18	435
Winter	12	445	16	505
T. vulpis				
Total	53	440	58	430
Summer	19	340	20	510
Fall	21	510	25	385
Winter	13	445	13	415
Toxocara				
Total	92	705	106	1165
Summer	30	800	32	1155
Fall	33	590	36	1125
Winter	29	875	38	1205

[1] Antilog of the mean of the logs of positive samples expressed as number of eggs/kg dry weight.

TABLE 39. DENSITIES OF EGGS OF ASCARIS, TRICHURIS TRICHIURA, T. VULPIS AND TOXOCARA IN POSITIVE SAMPLES OF AEROBIC, ANAEROBIC AND IMHOFF DIGESTION SLUDGES FROM FOUR NORTHERN STATES AS A FUNCTION OF SLUDGE TYPE

	VIABLE EGGS		TOTAL EGGS (VIABLE AND NONVIABLE)	
	N	Geometric Mean[1]	N	Geometric Mean[1]
Ascaris				
Total	61	1695	69	1860
Aerobic	5	4090	6	3000
Anaerobic	54	1720	58	2150
Imhoff	2	125	5	190
T. trichiura				
Total	31	425	49	475
Aerobic	3	460	3	460
Anaerobic	27	450	38	600
Imhoff	1	75	8	150
T. vulpis				
Total	53	440	58	430
Aerobic	8	345	8	345
Anaerobic	39	475	42	485
Imhoff	6	395	8	290
Toxocara				
Total	92	725	106	1165
Aerobic	16	1320	17	1410
Anaerobic	60	740	71	1155
Imhoff	16	375	18	1000

[1] Antilog of the mean of the logs of positive samples expressed as number of eggs/kg dry weight.

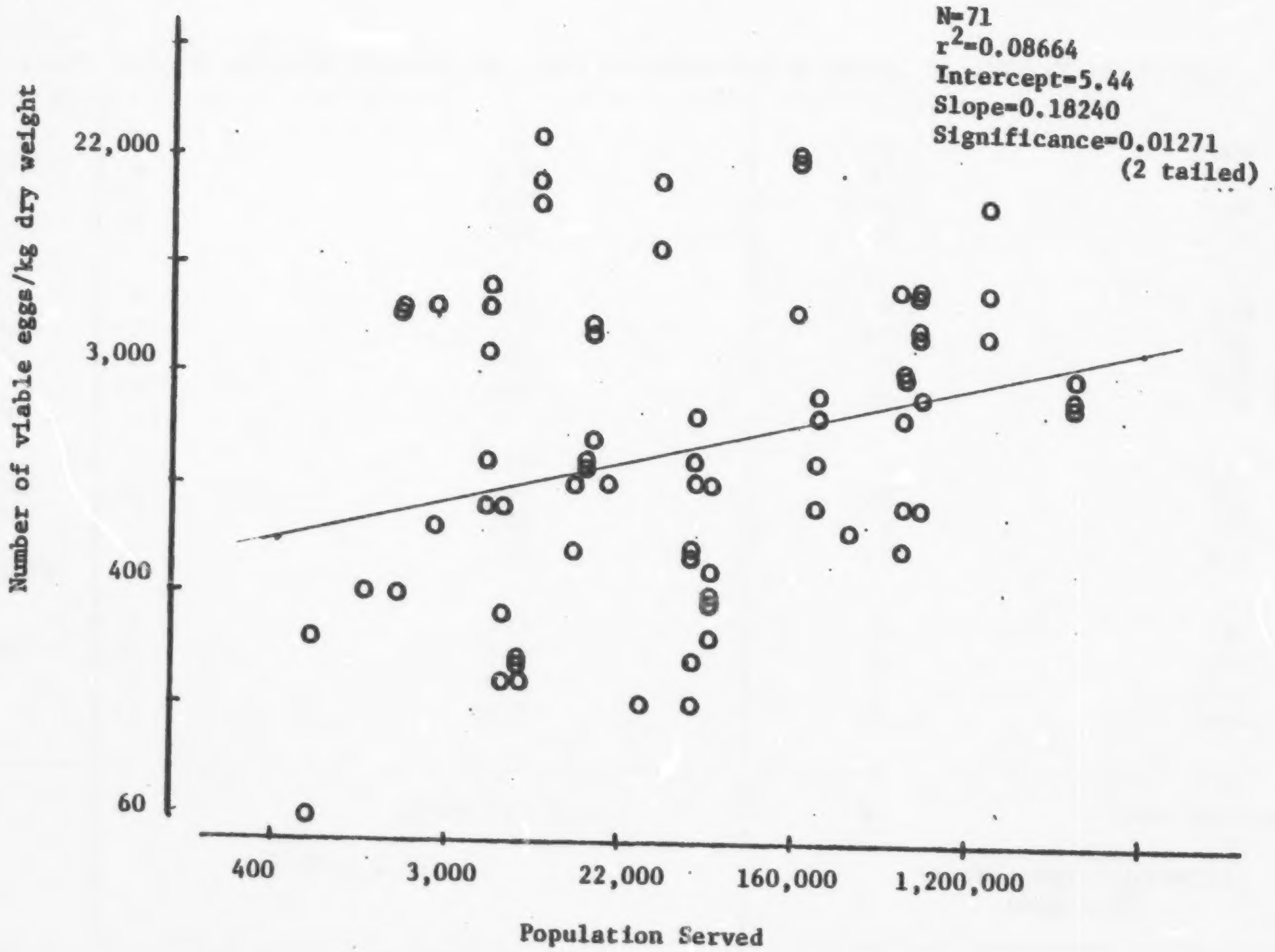


Figure 13. Viable *Ascaris* eggs in positive samples of digested sludge vs. population served by the treatment plant: northern states.

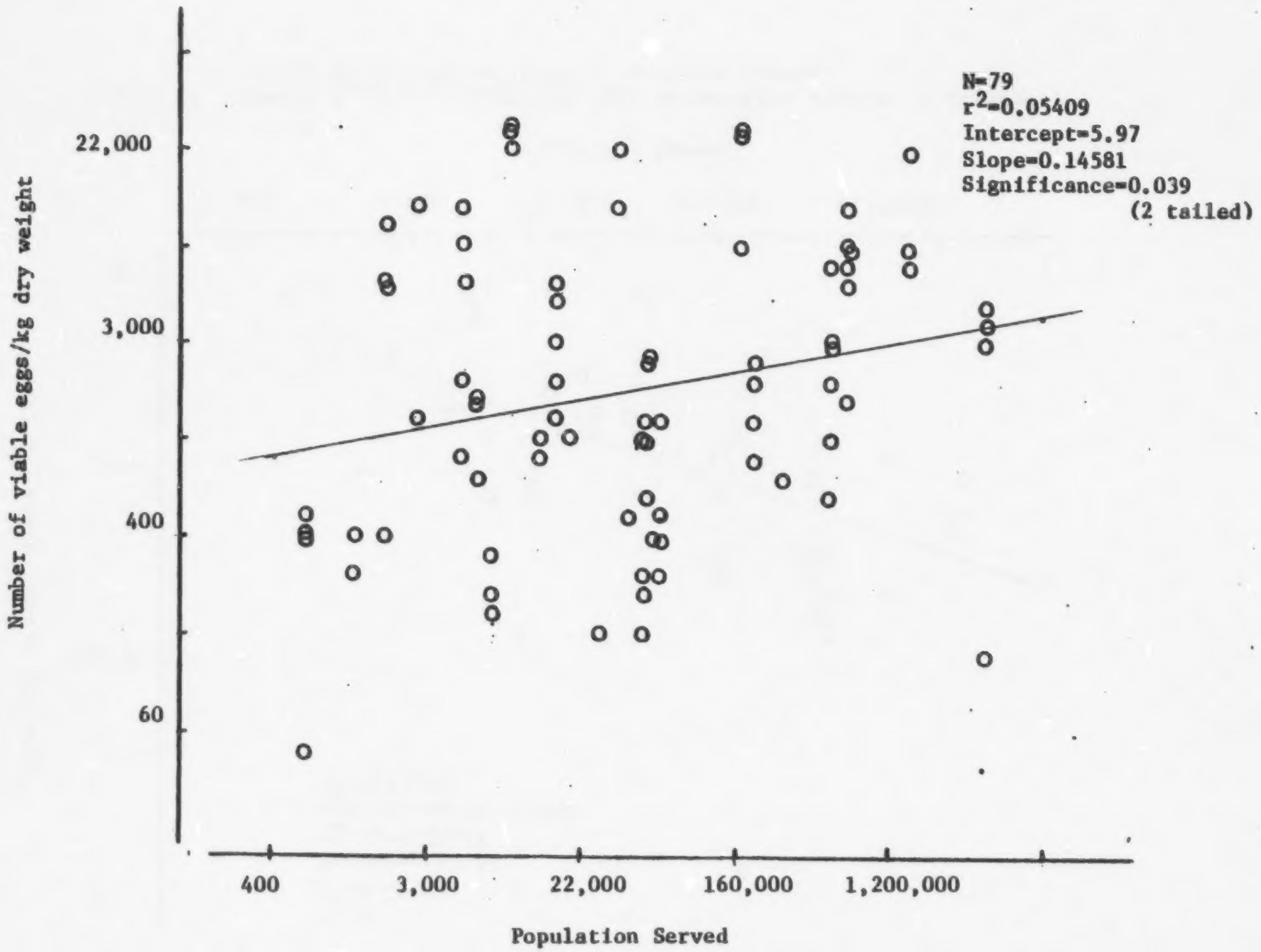


Figure 14. Total *Ascaris* eggs (viable and nonviable) in positive samples of digester sludge vs. population served: northern states.

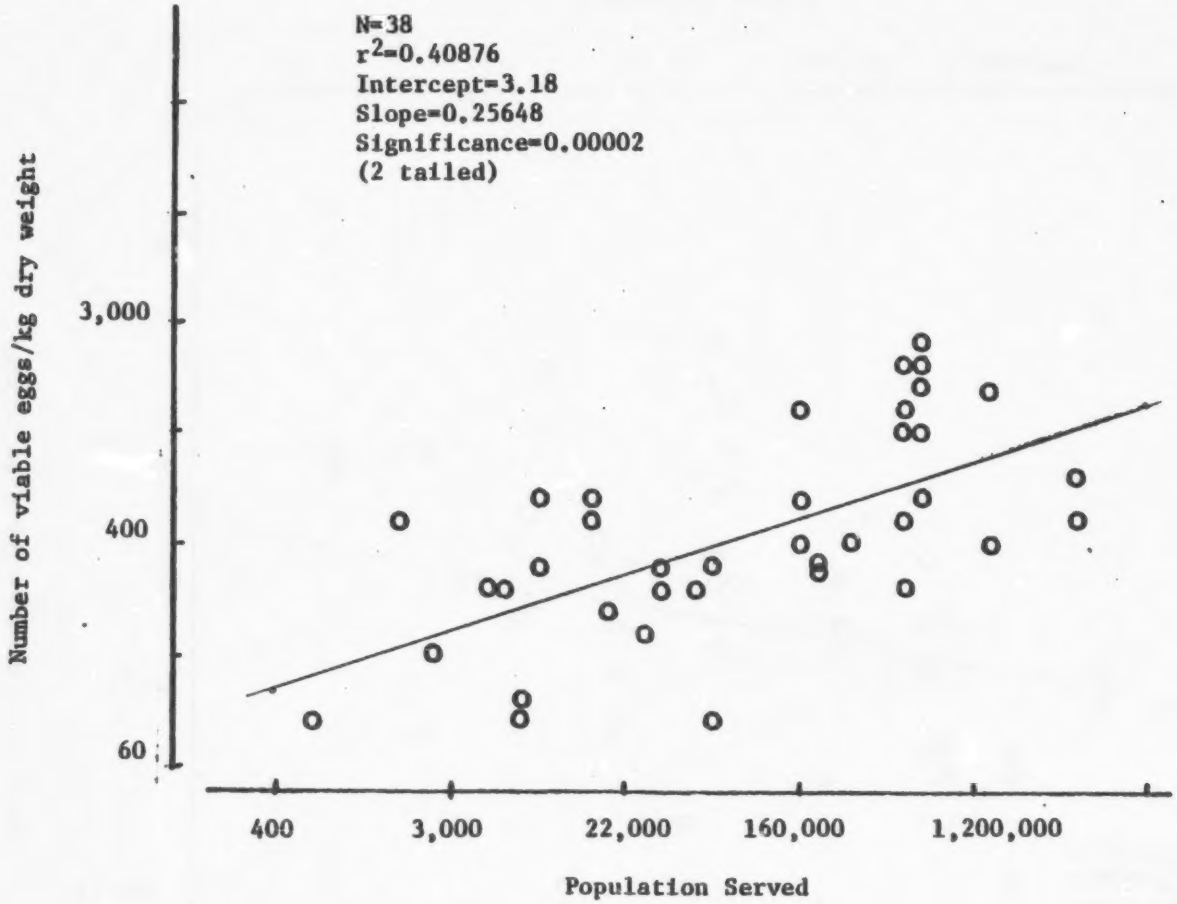


Figure 15. Viable *Trichuris trichiura* eggs in positive samples of digester sludge vs. population served: northern states.

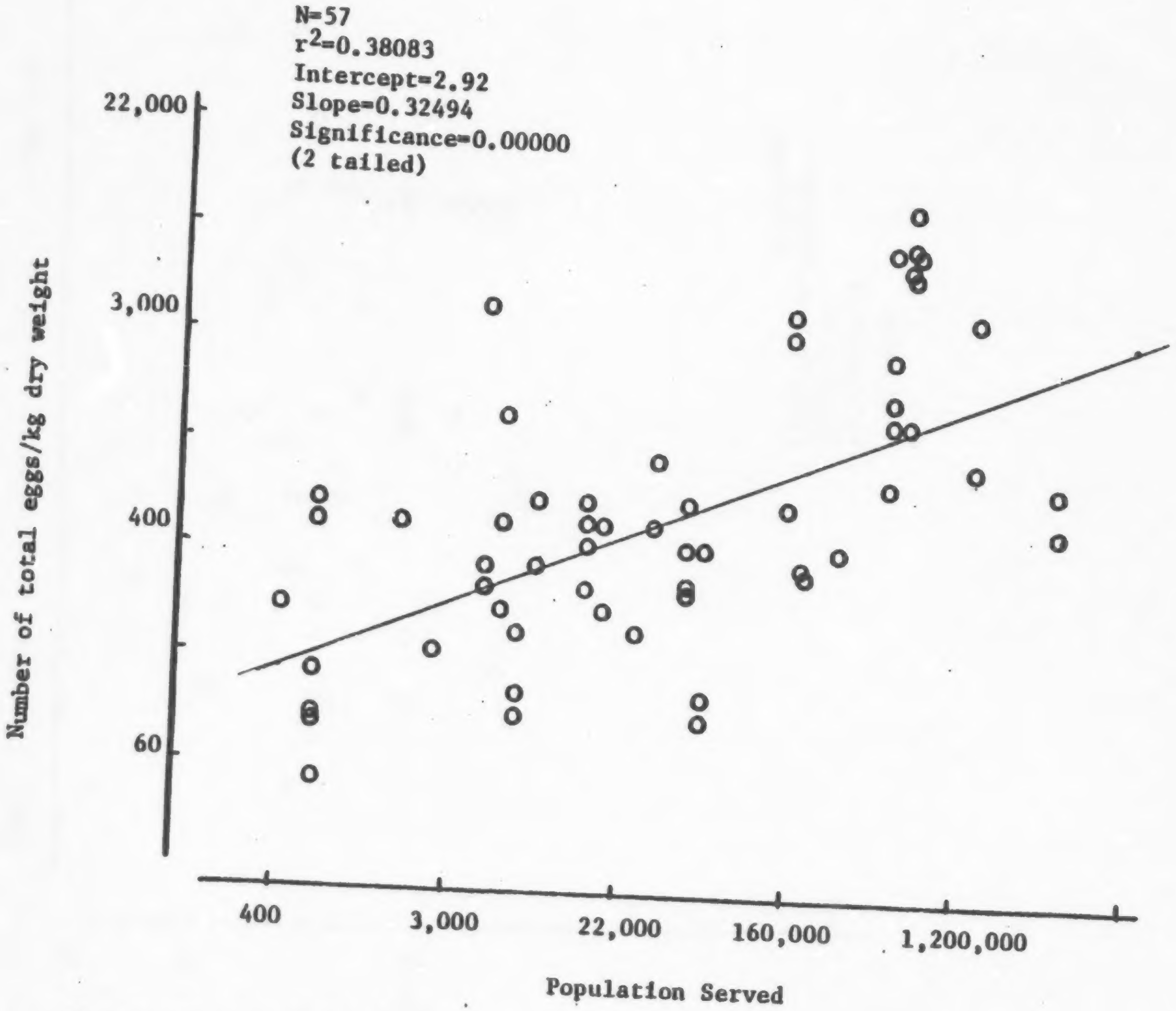


Figure 16: Total Trichuris trichiura eggs (viable and nonviable) in positive samples of digester sludge vs. population served: northern states.

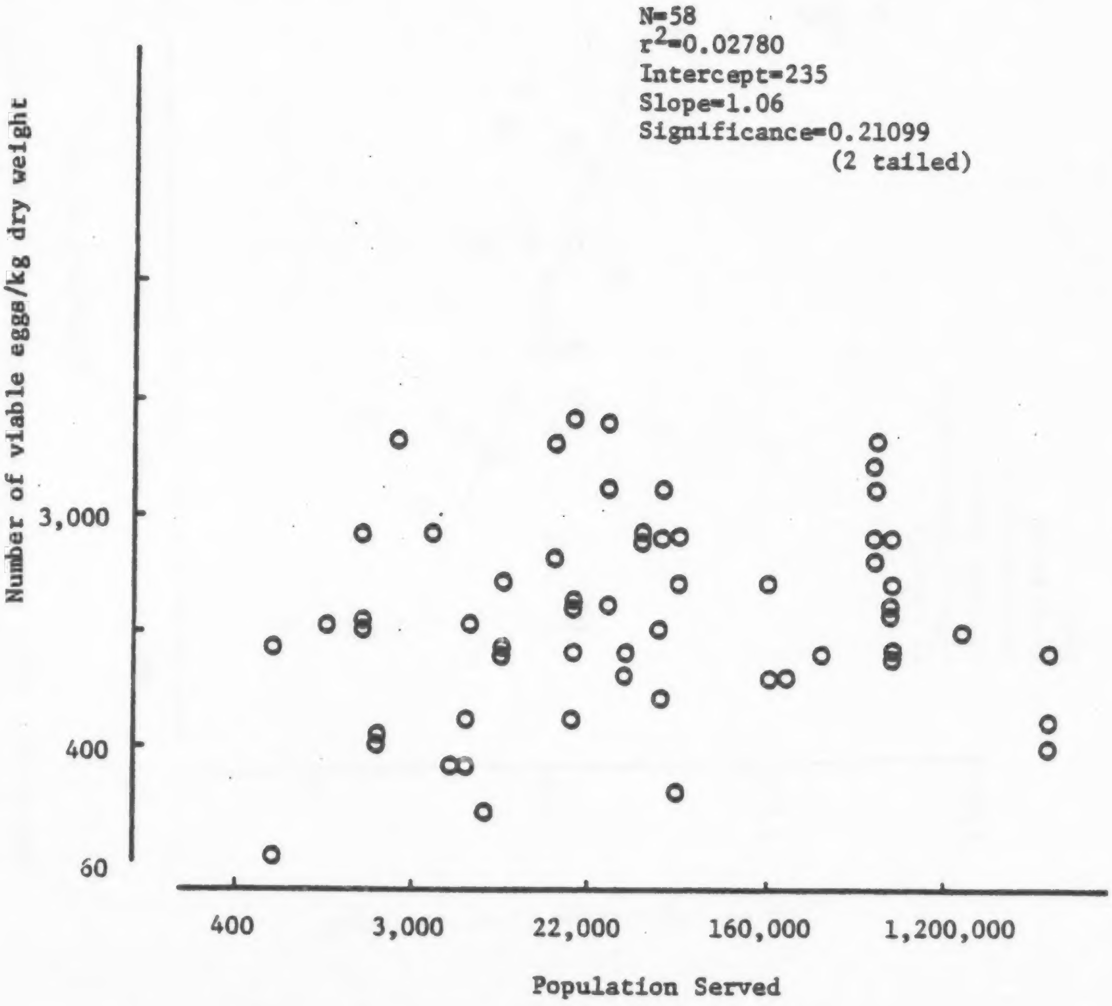


Figure 17. Viable Trichuris vulpis eggs in positive samples of digested sludge vs. population served: northern states.

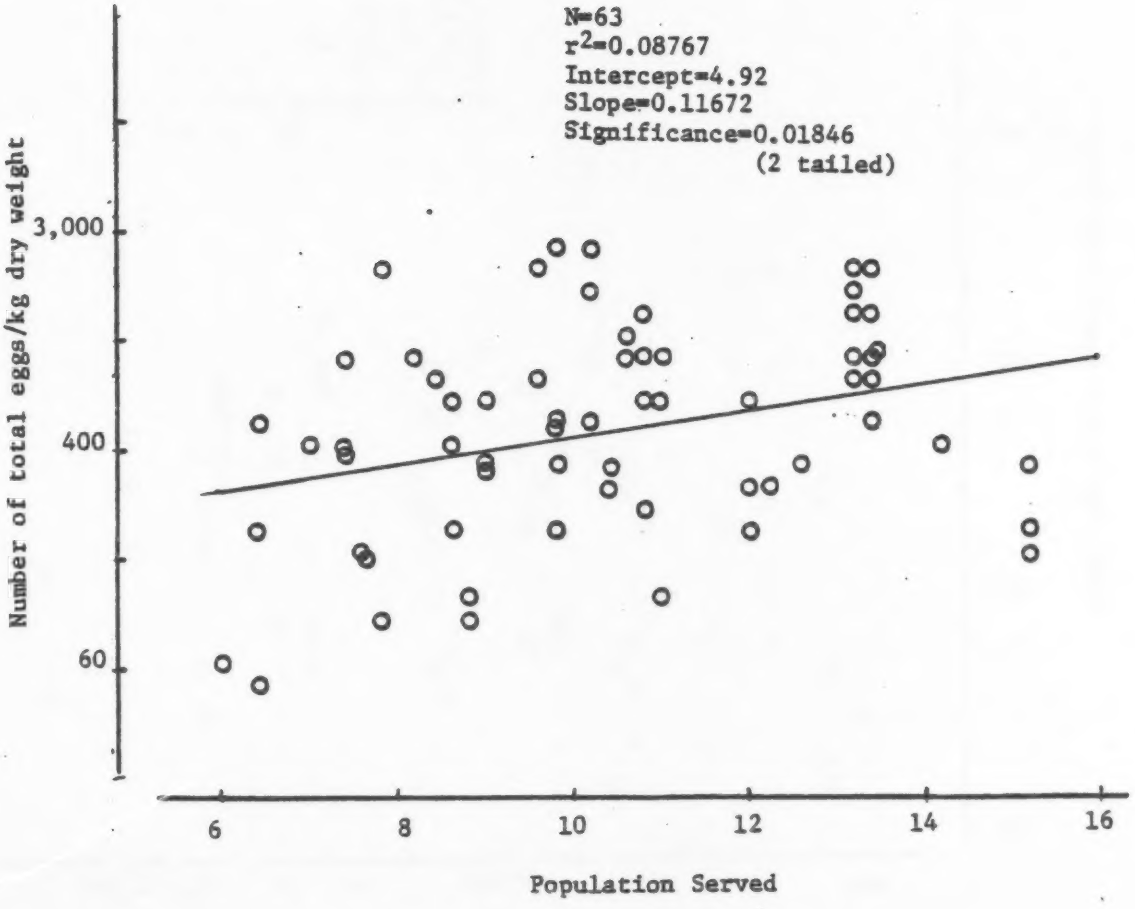


Figure 18. Total *Trichuris vulpis* eggs (viable and nonviable) in positive samples of digester sludge vs. population served: northern states.

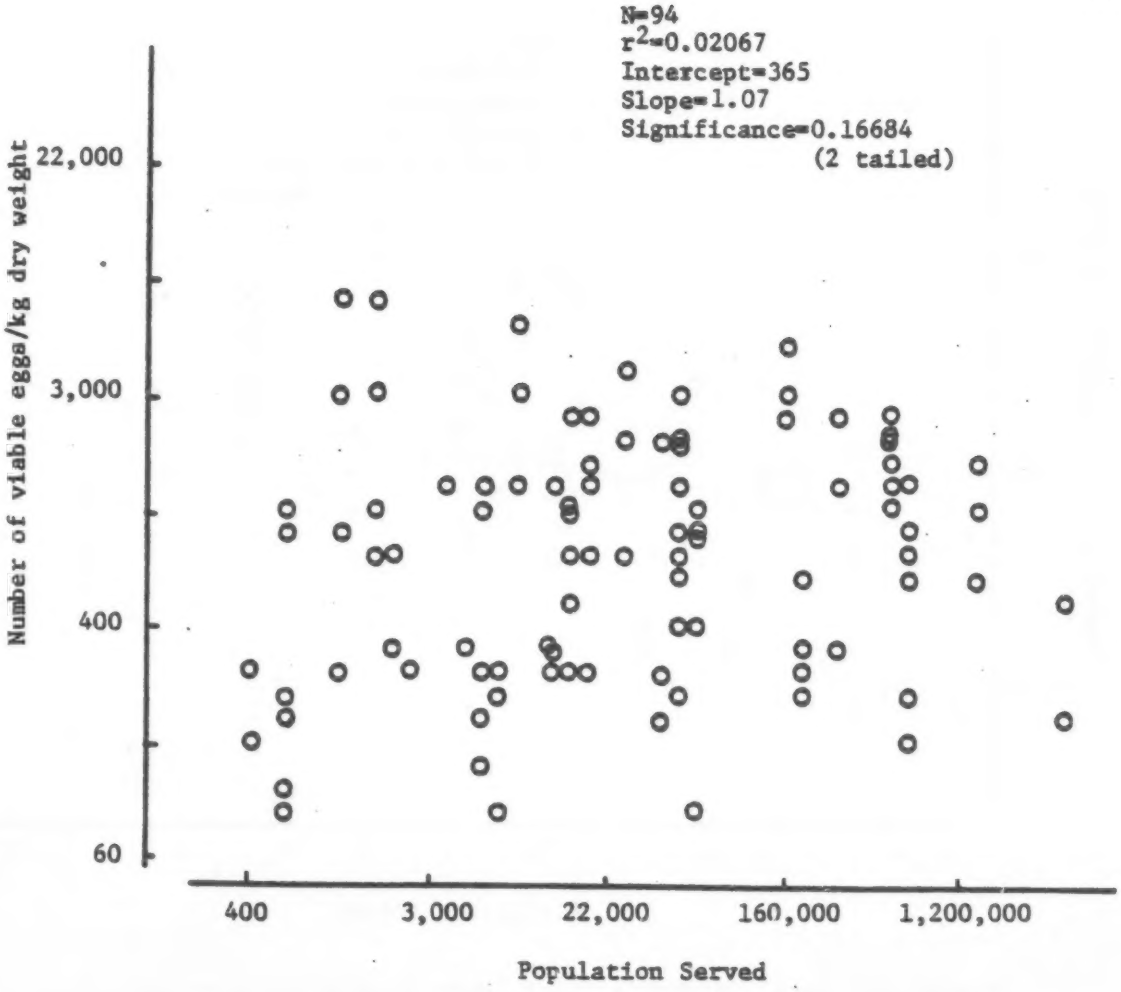


Figure 19. Viable Toxocara eggs in positive samples of digester sludge vs population served: northern states.

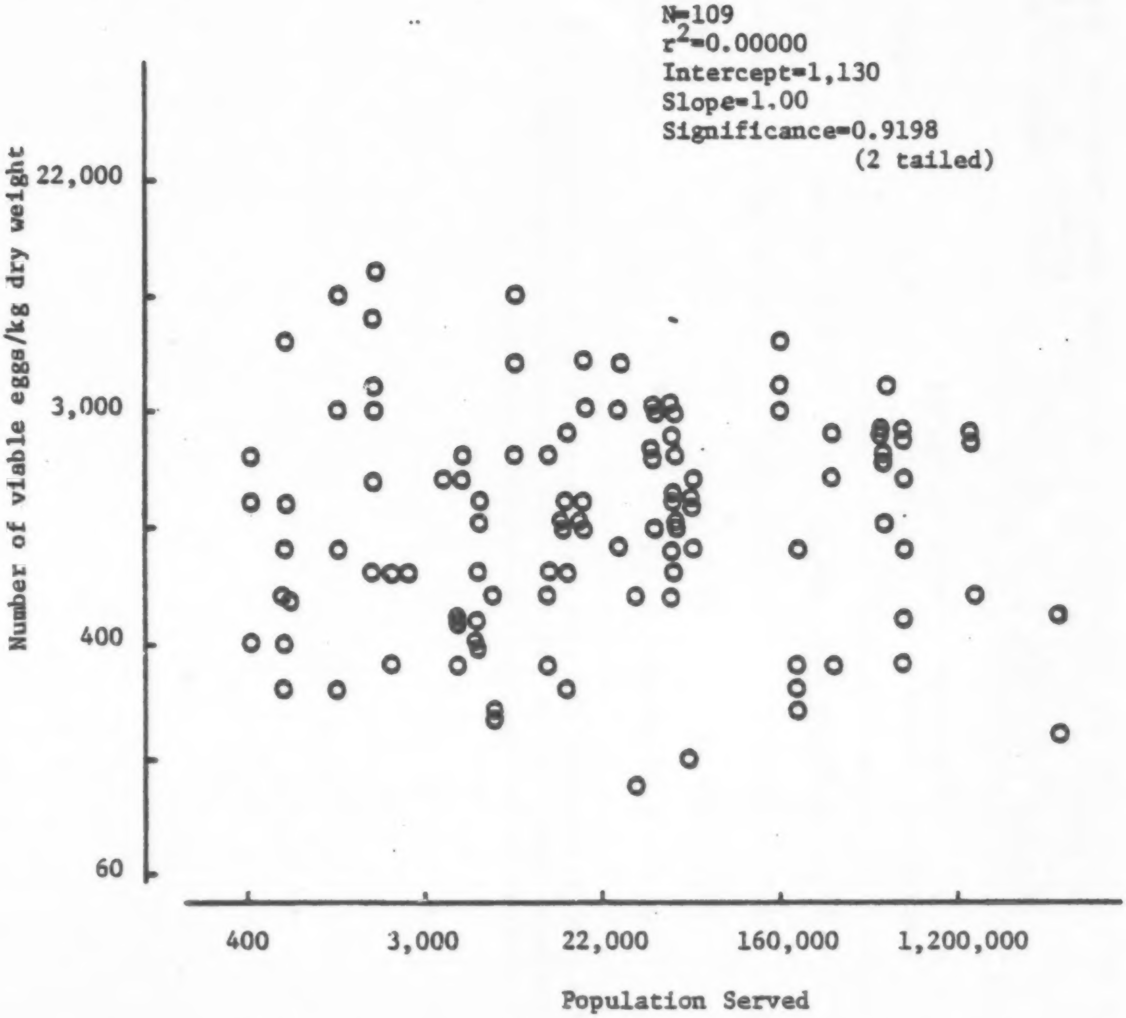


Figure 20. Total Toxocara eggs (viable and nonviable) in positive samples of digester sludge vs. population served: northern states.

TABLE 40. ANALYSIS OF THE RELATIONSHIP OF POPULATION, MEAT PROCESSING, STATE, DIGESTION AND SEASON TO THE DENSITY OF VIABLE EGGS OF *ASCARIS*, *TRICHURIS TRICHIURA*, *T. VULPIS* AND *TOXOCARA* IN POSITIVE SAMPLES OF AEROBIC, ANAEROBIC AND IMHOFF DIGESTER SLUDGE FROM FOUR NORTHERN STATES[1]

Parasite	No. of samples	Population served	Meat Processing wastes	State	Digestion	Season
Ascaris	61	$0.05>p>0.01$	$p>0.25$	$0.01>p>0.001$	$0.05>p>0.01$	NS
T. Trichiura	31	$p<0.001$	$0.01>p>0.001$	$0.17>p>0.05$	$0.25>p>0.10$	NS
T. vulpis	50	$p>0.25$	$0.25>p>0.10$	NS	NS	NS
Toxocara	85	$0.25>p>0.10$	0.25 p 0.10	NS	$0.01>p>0.001$	NS

---

[1] This is the probability that the listed parameter is by chance associated with the density level of parasite eggs. If the parameter was observed to be significant ($p \leq 0.05$), it was taken into account in the testing of subsequent parameters.

TABLE 41. ANALYSIS OF THE RELATIONSHIP OF POPULATION, MEAT PROCESSING WASTES, STATE, DIGESTION AND SEASON TO THE DENSITY OF VIABLE AND NONVIABLE EGGS OF *ASCARIS*, *TRICHURIS TRICHIURA*, *T. VULPIS* AND *TOXOCARA* IN POSITIVE SAMPLES OF AEROBIC, ANAEROBIC AND IMHOFF DIGESTER SLUDGE FROM FOUR NORTHERN STATES[1]

Parasite	No. of samples	Population served	Meat Processing wastes	State	Digestion	Season
Ascaris	69	$0.05>p>0.01$	$p>0.25$	$0.05>p>0.01$	$0.25>p>0.10$	NS
T. Trichiura	48	$p<0.001$	$0.01>p>0.001$	$p<0.001$	NS	NS
T. vulpis	55	$0.01>p>0.05$	$0.05>p>0.01$	NS	NS	NS
Toxocara	99	NS	$0.1>p>0.05$	NS	NS	NS

---

[1] This is the probability that the listed parameter is by chance associated with the density level of parasite eggs. If the parameter was observed to be significant ($p \leq 0.05$), it was taken into account in the testing of subsequent parameters.

Since a relationship was found between the densities of *Ascaris*, *T. trichiura*, and *T. vulpis* eggs and population size, a step-up regression analysis was used, controlling for the effects of population size, and testing the significance of the effects of meat processing wastes, state of sample, season of sample, and type of digestion process (aerobic, anaerobic or Imhoff) on the densities of viable and total eggs in the sludge (Tables 40 and 41).

The presence of meat processing wastes was not significantly associated with increases in viable or total *Ascaris* egg densities ($p > 0.25$). A change in the densities of viable and total *T. trichiura* eggs was found to be associated with the presence of meat processing wastes ($0.01 > p > 0.001$), with fewer eggs being found when meat wastes were present. Total *T. vulpis* eggs in positive aerobic, anaerobic and Imhoff digestion sludges were less numerous when meat processing wastes were present ($0.05 > p > 0.01$) although viable *T. vulpis* eggs were not ($0.25 > p > 0.10$). The presence of meat treatment wastes was not associated with changes in viable ($0.10 > p > 0.05$) or total ($0.25 > p > 0.10$) *Toxocara* egg densities.

Significant differences in the densities of both viable ($0.01 > p > 0.001$) and total ($0.05 > p > 0.01$) *Ascaris* eggs were found between states. Fewer viable eggs were found in Ohio digested sludge than in those from Minnesota. No other differences between the other states were noted. Significant differences in total *T. trichiura* egg densities were also found between states ($p > 0.001$), although this was not the case for viable eggs ($0.10 > p > 0.05$). Fewer total *T. trichiura* eggs were found in Ohio digested sludges than in those from Minnesota. No other differences in *T. trichiura* densities between the states were noted.

No significant differences in egg densities between the states were noted for either *T. vulpis* or *Toxocara*.

While the type of digestion process sampled was not found to be significantly associated with the total egg densities for *Ascaris*, *T. trichiura*, *T. vulpis* or *Toxocara*, digestion process was found to be significant with respect to viable *Ascaris* ($0.05 > p > 0.01$) and *Toxocara* ($0.01 > p > 0.001$) densities, with fewer viable eggs being found in the anaerobic digesters than in aerobic digesters. This was not found for *T. trichiura* and *T.* vulpis, however.

The season in which the sample was obtained was not found to be significant with respect to changes in viable or total *Ascaris*, *T. trichiura*, *T. vulpis* or *Toxocara* densities in digester sludges.

Northern Stabilized Sludges—

Zimpro, Composting, Lime Stabilization and Laggon Storage—

One plant (Plant #211) used the Zimpro process for sludge treatment. No viable *Ascaris*, *T. trichiura*, *T. vulpis* or *Toxocara* eggs were found in samples following the heat-treatment or vacuum filter cake taken after heat-treatment on any of the three trips, even though viable eggs were recovered from pre-treatment sludge samples. One nonviable Ascaris egg was found in a Zimpro sample.

A second plant (Plant #303) utilized composting of stored primary sludge. Although Ascaris, T. trichiura, T. vulpis and Toxocara eggs were recovered from primary and stored primary samples, no eggs were recovered from any of the compost samples during the three trips.

A third plant (Plant #408) limed its primary sludge and sent it to a lagoon. Numerous viable eggs of Ascaris and T. trichiura were recovered from this plant's lagoon sludges. No viable Toxocara eggs were ever found in the three sludge samples from lagoons, even though they were present in two of the three primary sludge samples. No T. vulpis eggs were recovered from any of the sludge samples.

Table 42 assesses the reduction of eggs of viable Ascaris, Toxocara, T. trichiura, and T. vulpis eggs in two sludge storage lagoons in Minnesota. The influent sludges to the lagoons were stabilized by anaerobic digestion. There was no difference in number of any of the parasites during the winter, but during the fall and summer, fewer eggs of Ascaris, T. trichiura, and T. vulpis were noted. Little change was noted in densities of Toxocara eggs in fall and winter.

Northern Drying Bed Sludges—

Semi-log scatterplots of the density of viable eggs in positive drying bed and covered drying bed sludge samples vs the percent moisture content of that drying bed sample are presented in Figures 21 through 25 for Ascaris, T. trichiura, T. vulpis and Toxocara. In all cases a significant relationship between the density of viable eggs and the moisture content of of the sample was observed. As the moisture content decreased, the densities of viable parasite eggs decreased.

Scatterplots of the log of the density of viable eggs in the drying beds vs the log of the density of viable eggs in the undigested sludge are presented in Figures 26 and 27 for Ascaris and Toxocara eggs, respectively. Too few T. trichiura and T. vulpis data points were available to permit similar plots with their eggs.

Step-up regression analyses were applied to these data to test the significance of the effects of the percent moisture content of the drying bed sample, the age of the sludge in the bed, the season of sampling and the type of digestion process undergone on the density of viable eggs in the drying bed. For these analyses, Imhoff digestion sludges were grouped with anaerobically digested sludges for comparison to aerobically digested sludges.

As can be seen in Table 43, when one controls for age of sludges, season, and type of digestion, the percent moisture content of the drying

TABLE 42. DECREASE IN DENSITY OF VIABLE EGGS OF ASCARIS, TRICHURIS TRICHIURA, T. VULPIS AND TOXOCARA IN LAGOON-STORED SLUDGE IN TWO PLANTS IN MINNESOTA

	ASCARIS						T. TRICHIURA					
	FALL		WINTER		SUMMER		FALL		WINTER		SUMMER	
Type of sludge	No.[1]	% red.[2]	No.	% red.	No.	% red.	No.	% red.	No.	% red.	No.	% red.
Plant No. 113												
Undigested	0	NA[3]	131	NA	0	NA	244	NA	0	NA	0	NA
Digested	0	--[4]	556	(324%)[5]	0	—	294	(20%)	0	—	0	—
Lagooned	0	--	278	50%	104	(—)	0	100%	0	—	0	—
Effect of lagooning	Undetermined		No effect		Undertermined		Possible effect		Undetermined		Undertermined	
Plant No. 115												
Undigested	270	NA	333	NA	294	NA	0	NA	0	NA	0	NA
Digested	1304	(383%)	500	(50%)	2000	(580%)	0	—	0	—	0	—
Lagooned	286	78%	789	58%	0	100%	0	—	131	(—)	0	—
Effect of lagooning	Possible effect		No effect		Possible effect		Undertermined		Undertermined		Undertermined	

- Continued -

TABLE 42. (Continued)

	T. VULPIS						TOXOCARA					
	FALL		WINTER		SUMMER		FALL		WINTER		SUMMER	
Type of sludge	No.[1]	% red.[2]	No.	% red.	No.	% red.	No.	% red.	No.	% red.	No.	% red.
Plant No. 113												
Undigested	0	NA	0	NA	0	NA	244	NA	131	NA	196	NA
Digested	0	—	0	—	0	—	882	(261)	0	100	1492	(629%)
Lagooned	0	—	0	—	0	—	938	(6%)	-	—	0	100%
Effect of lagooning	Underternined		Underternined		Underternined		No effect		Underternined		Possible effect	
Plant No. 115												
Undigested	0	NA	666	NA	0	NA	811	NA	1334	NA	0	NA
Digested	870	(--)	0	100%	1333	(—)	2174	(168%)	2500	(87%)	667	(--)
Lagooned	0	100%	790	(--)	50	96%	1714	20%	3550	(42%)	98	85%
Effect of lagooning	Possible effect		No effect		Possible effect		No effect		No effect		Possible effect	

---

[1] Number of viable eggs per kg dry solids.

[2] Percent reduction of viable eggs as compared to eggs in sample of digested sludge (for lagooned sludge) or eggs in sample of undigested sludge (for digested sludge).

[3] NA = Not Applicable.

[4] -- = Not able to calculate.

[5] ( ) = Increase.

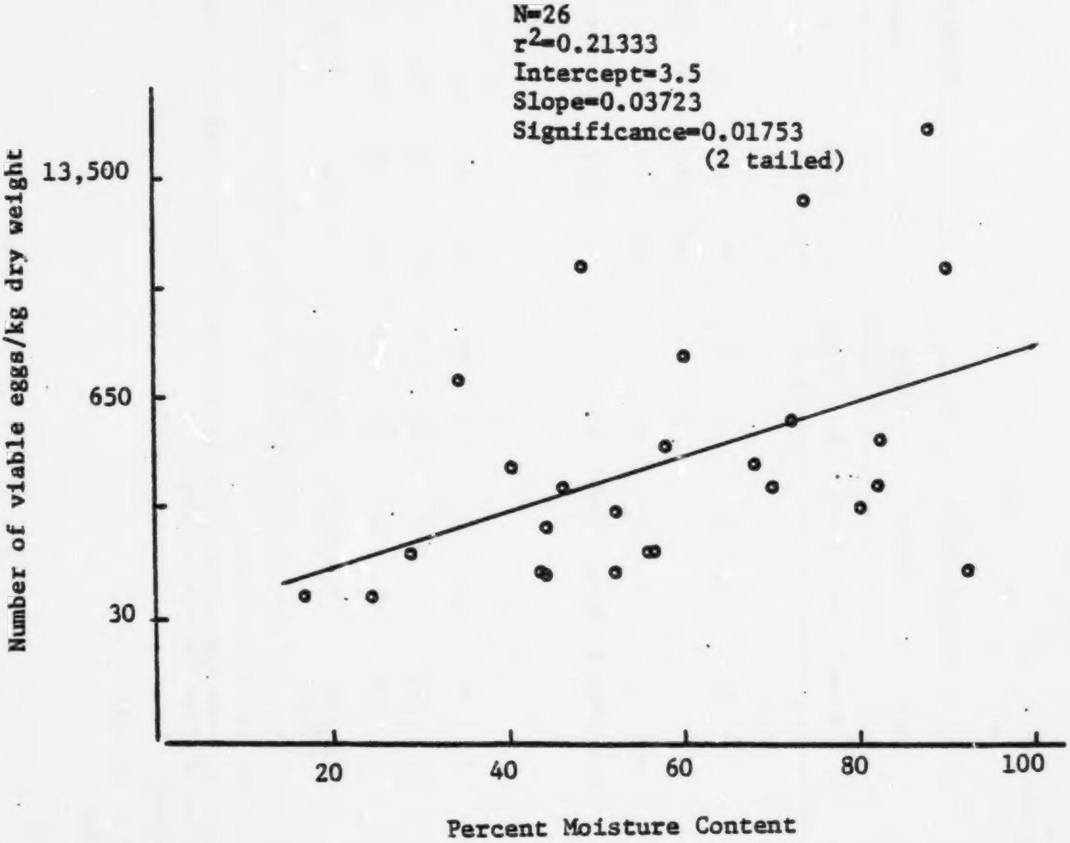


Figure 21. Viable *Ascaris* eggs in positive samples of drying bed sludges vs. percent moisture content of that sludge: northern states.

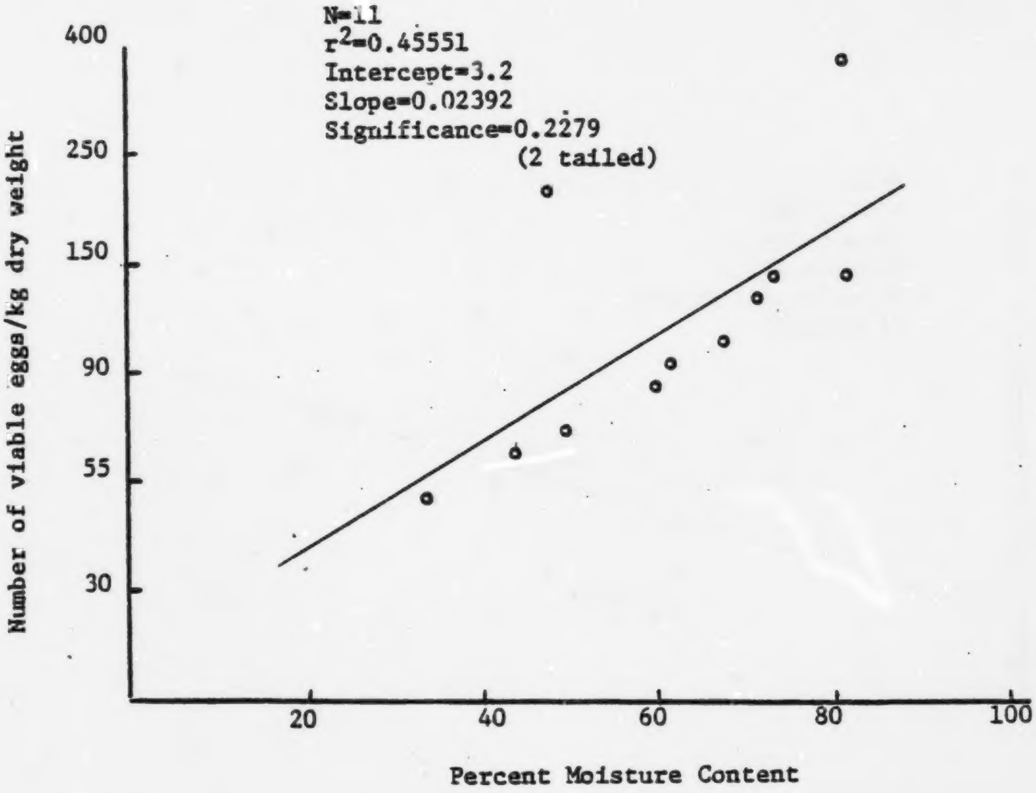


Figure 22. Viable *Trichuris trichiura* eggs in positive samples of drying bed sludges vs. percent moisture content of that sludge: northern states.

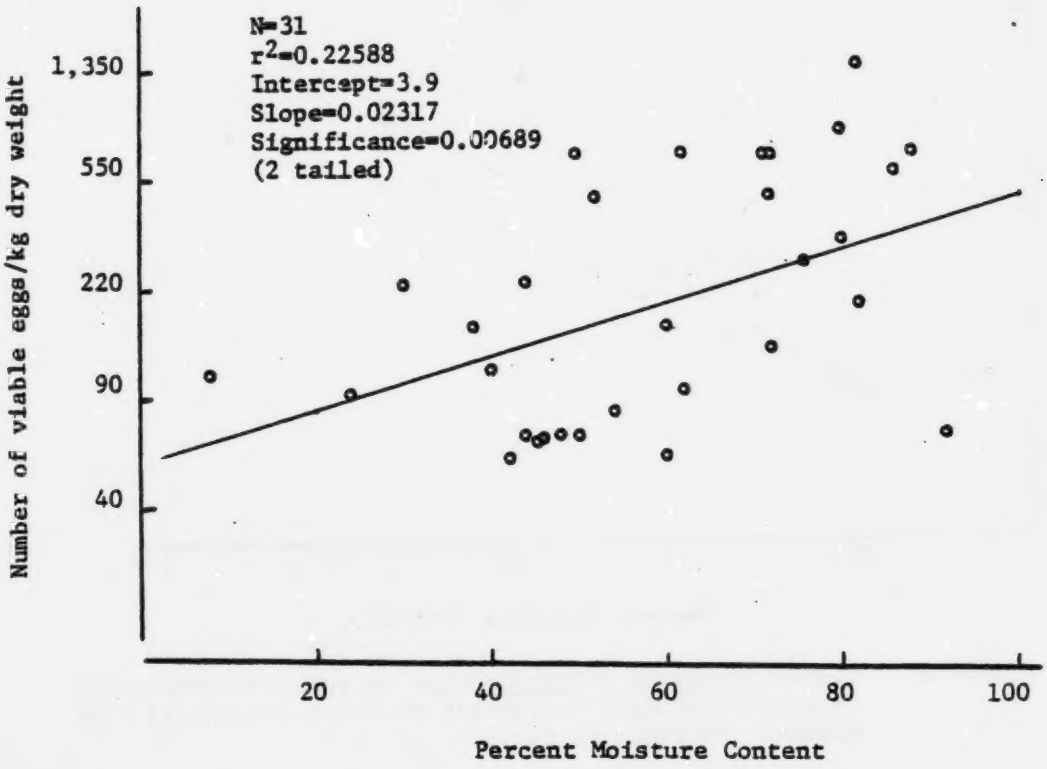


Figure 23. Viable *Trichuris vulpis* eggs in positive samples of drying bed sludges vs. percent moisture of that sludge: northern states.

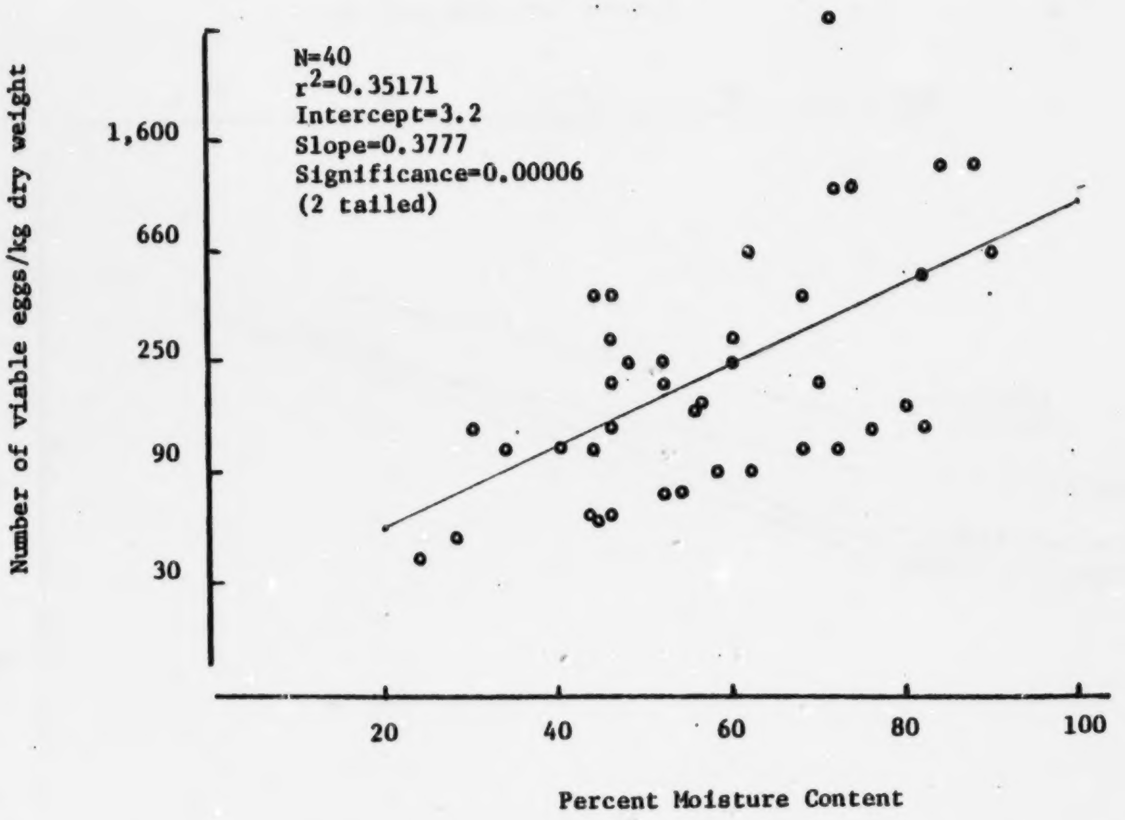


Figure 24. Viable *Toxocara* eggs in positive samples of drying bed sludges vs. percent moisture content of that sludge: northern states.

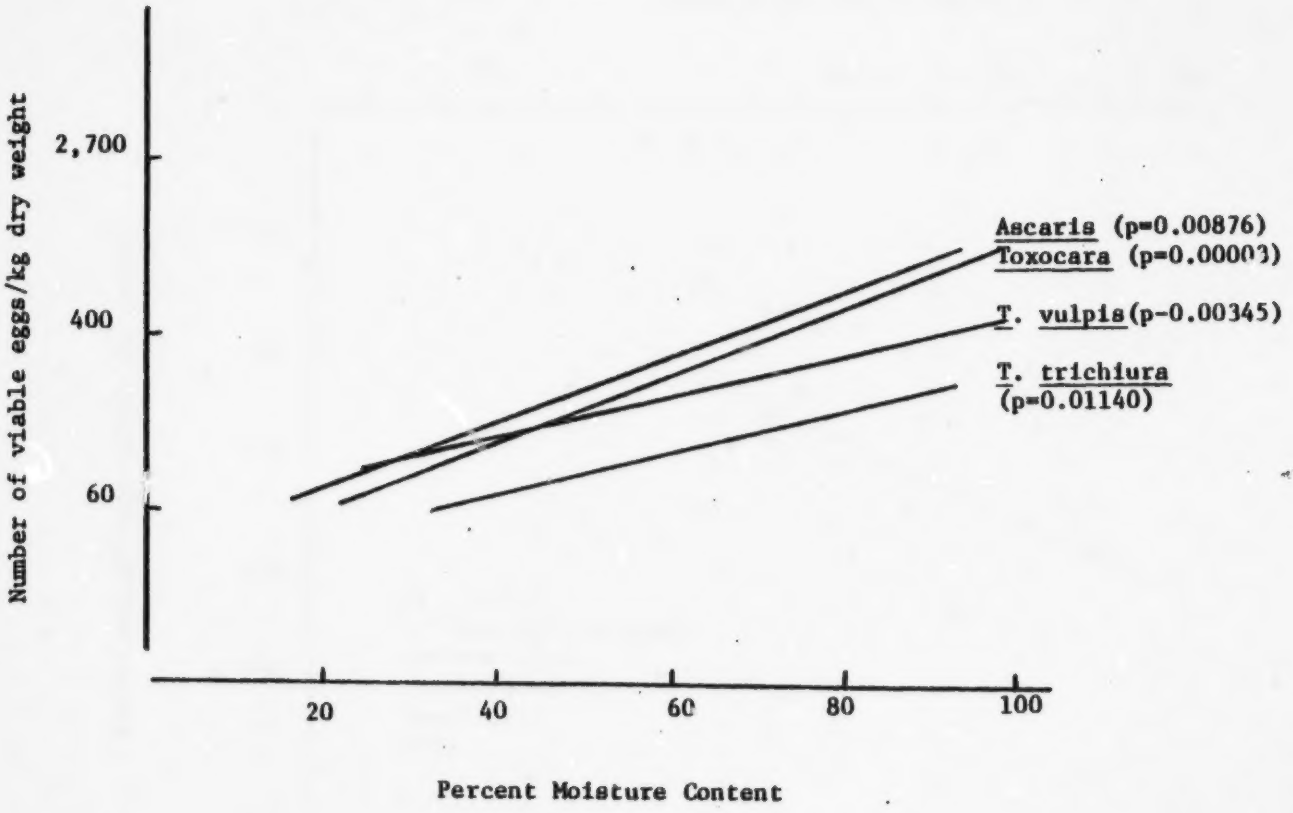


Figure 25. Viable eggs of _Ascaris_, _Trichuris trichiura_, _T. vulpis_ and _Toxocara_ in positive samples of drying bed sludges vs. percent moisture content of that sludge: northern states.

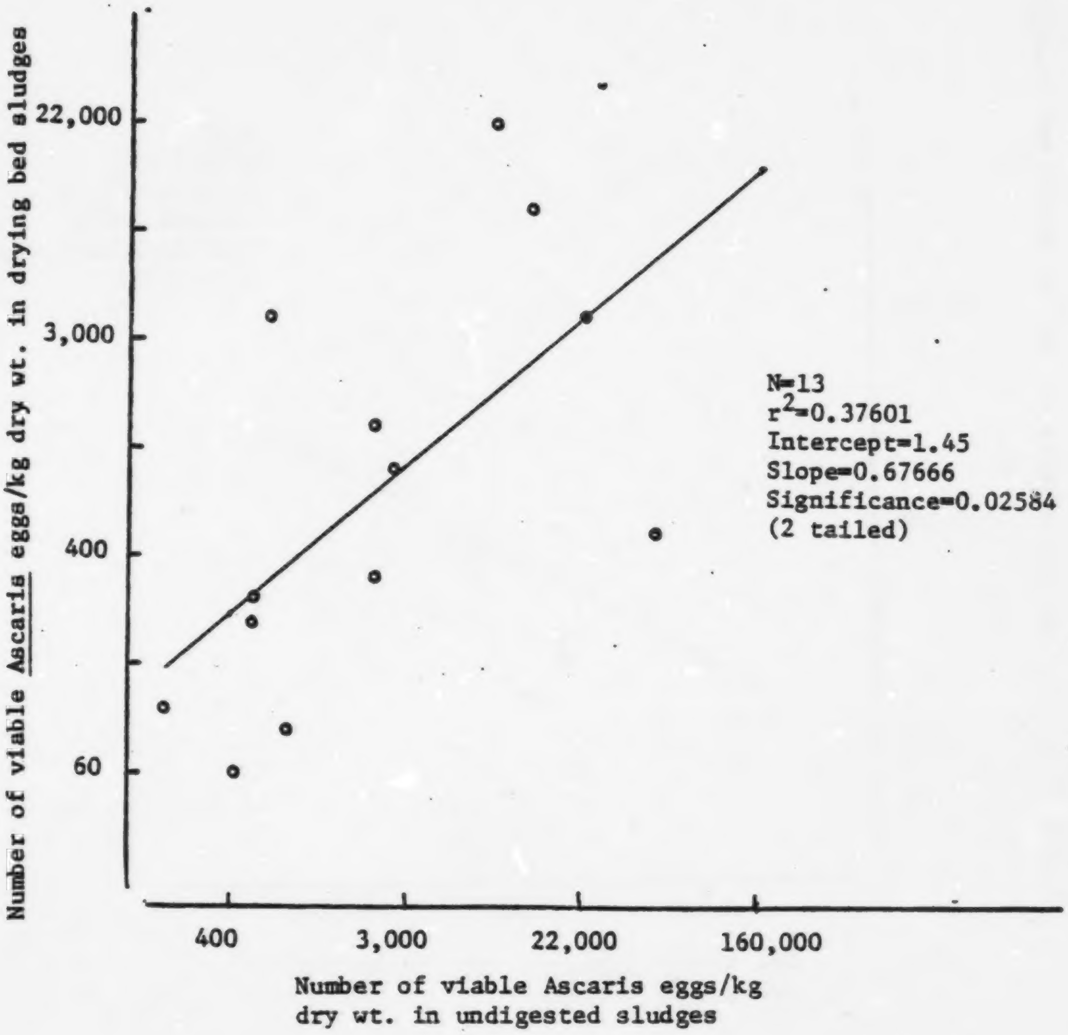


Figure 26. Viable *Ascaris* eggs in positive samples of drying bed sludges vs. viable *Ascaris* in positive samples of undigested sludges: northern states.

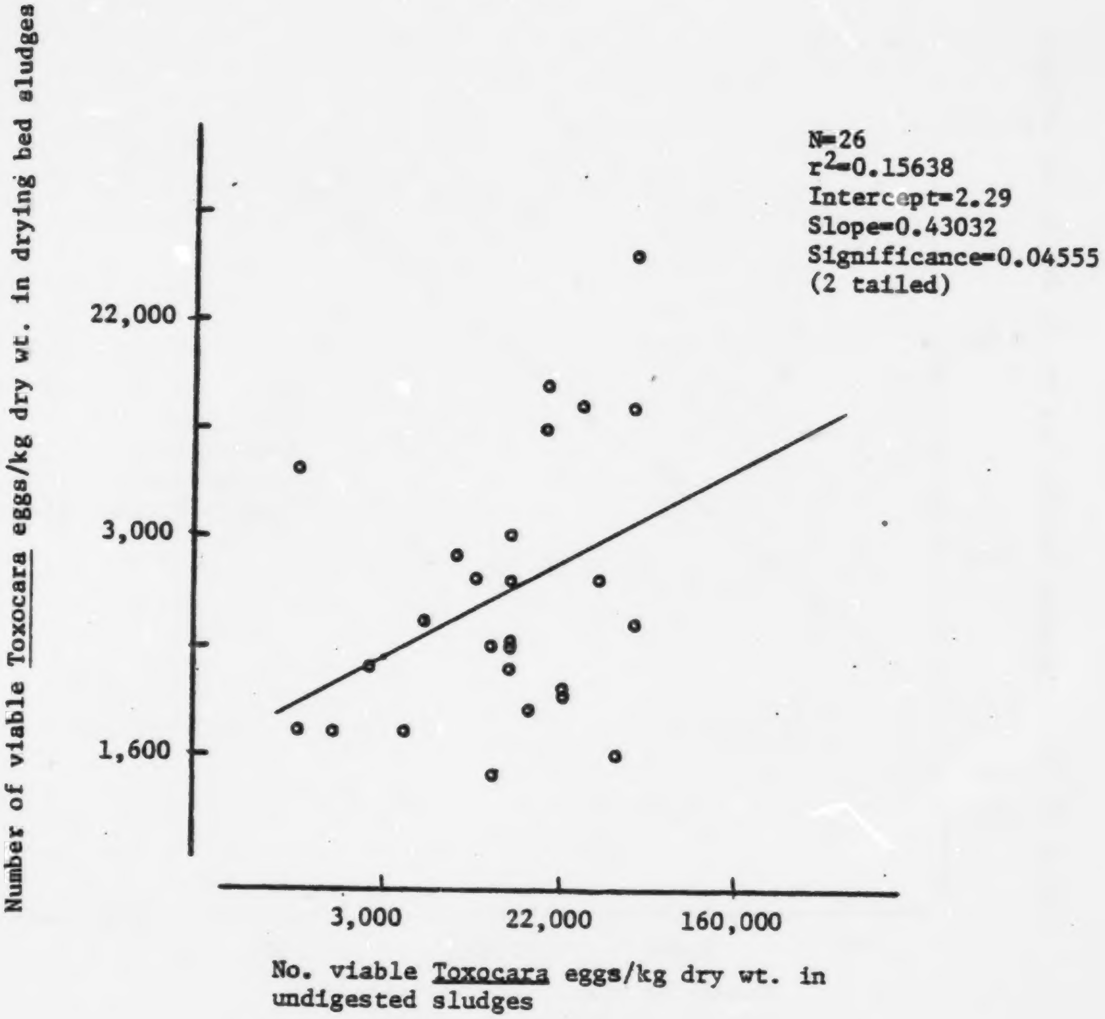


Figure 27. Viable *Toxocara* eggs in positive samples of drying bed sludges vs. viable *Toxocara* eggs in positive undigested sludges: northern states.

TABLE 43. ANALYSIS OF THE RELATIONSHIP OF PERCENT MOISTURE, SLUDGE AGE, DIGESTION PROCESS AND SEASON TO THE DENSITY OF VIABLE *ASCARIS* AND *TOXOCARA* EGGS FOUND IN POSITIVE SAMPLES OF DRYING BED SLUDGES FROM FOUR NORTHERN STATES

Parasite	No. of samples	No. of viable eggs in influent	Percent moisture	Sludge	Digestion type	Season
Ascaris	13	$0.05>p>0.01$	$p>0.25$	$p>0.25$	$p>0.25$	$0.05>p>0.01$
Toxocara	26	$0.05>p>0.01$	$p<0.001$	$0.25>p>0.10$	$0.05>p>0.01$	$p>0.25$

[1] This is the probability that the listed parameter is by chance associated with the density level of parasite eggs. If the parameter was observed to be significant ($p \leq 0.05$) it was taken into account in the testing of subsequent parameters.

TABLE 44. NUMBER OF SAMPLES IN WHICH THERE WAS A REDUCTION IN THE DENSITIES OF VIABLE EGGS OF *ASCARIS*, *TRICHURIS TRICHIURA*, *T. VULPIS* AND *TOXOCARA* IN DRYING BED AND COVERED DRYING SAMPLES, AS COMPARED TO VIABLE EGG DENSITIES IN SIMULTANEOUS DIGESTER SAMPLES FROM PLANTS IN FOUR NORTHERN STATES

NUMBER OF SAMPLES

	Percent reduction					
Parasite	≤ 0	1 - 50	51 - 75	76 - 100	> 100	TOTAL
Ascaris	1	2	1	8	10	22
T. trichiura	0	1	0	3	10	14
T. vulpis	6	2	3	6	11	28
Toxocara	3	4	8	10	17	42

bed sludge was not found to be significant with respect to viable *Ascaris* densities, although it was significant for viable *Toxocara* densities ($p < 0.001$). Fewer viable *Toxocara* eggs were found with decreasing sludge moisture content. The age of the sludge in the drying bed was not found to have a significant effect for either *Ascaris* ($0.25 > p > 0.10$) or *Toxocara* ($p > 0.25$) eggs. The type of digestion process was not significant with respect to *Ascaris* ($p > 0.25$) but was with *Toxocara* eggs ($0.05 > p > 0.01$), with fewer viable eggs in the drying bed associated with anaerobic processes than with aerobic. Significantly fewer *Ascaris* eggs were found in fall than in winter ($0.05 > p > 0.01$), while no seasonal differences were found for *Toxocara* eggs.

The reduction of densities of viable parasite eggs found in drying bed samples (covered and not covered) from those found in the corresponding digester samples are presented in Table 44. Well over half of all simultaneous samples showed 75-100% fewer viable *Ascaris*, *T. trichiura*, *T. vulpis* and *Toxocara* eggs in drying bed samples than in digester samples.

North and South Drying Bed Sludges—

Table 45 presents the moisture content of drying bed and covered drying bed sludge samples for the northern and southern states. Only five samples from the northern drying beds had a moisture content of less than 20%, which was previously found to be necessary for effective parasite egg inactivation, and three of these samples were from covered drying beds. The other two samples were from plants in the eastern part of Washington state. Overall, drying bed sludge samples from the southern states did not contain as high a moisture content as did those from the northern states.

TABLE 45. PERCENT MOISTURE CONTENT OF DRYING BED AND COVERED DRYING BED SLUDGE SAMPLES FROM PLANTS IN SOUTHERN AND NORTHERN STATES

	SOUTH		NORTH	
Moisture content	No. of samples	Percent of total	No. of samples	Percent of total
> 60%	14	15	28	38
40 - 60%	28	30	33	44
20 - 40%	20	22	8	11
< 20%	30	33	5	7
TOTAL	92	100	74	100

Scatterplots of the pooled north and south drying bed data are presented in Figures 28 to 31, in which the log densities of viable eggs in positive drying bed samples are plotted as a function of the log densities of viable eggs in positive samples of undigested sludges for Ascaris, T. trichiura, T. vulpis and Toxocara. Higher densities of viable Ascaris eggs in undigested sludges were significantly associated with higher densities of viable Ascaris eggs in drying bed sludges ($p < 0.0001$) (Figure 28). This was also true for the eggs of T. trichiura ($p < 0.03$) and T. vulpis ($p < 0.03$) (Figures 29 and 30). The densities of viable Toxocara eggs did not show a significant relationship, however (Figure 31).

A step-up multiple regression analysis was utilized, testing the significance of the effect of (1) percent moisture content of the drying bed sludge, (2) age of the sludge in the bed, and (3) digestion process (aerobic vs anaerobic) employed on the undigested sludge on this relationship.

Decreasing moisture content of the drying bed sludge was significantly associated with decreased densities of viable Ascaris ($0.01 > p > 0.001$), T. trichiura ($0.05 > p > 0.01$), T. vulpis $p < 0.001$) and Toxocara ($p < 0.001$) eggs (Table 46).

Increasing sludge age in drying beds was not associated with decreased densities of viable Ascaris ($p > 0.25$) or Toxocara ($p > 0.25$).

There was no significant decrease although a trend was noted in the densities of Ascaris and Toxocara eggs in anaerobic digestion type processes. No trend was observed for T. trichiura and T. vulpis eggs ($p > 0.25$).

Sludges Destined for Ultimate Disposal—

The methods of sludge disposal used by the 48 treatment plants in the four northern states are listed in Table 47. Sludge destined for disposal was dewatered sludge in 31 plants, liquid sludge (primary or digested) in 13 plants, and both dewatered and liquid sludge in 4 plants. In the majority of cases, the sludge was land-applied with only about one-third being placed in landfills, lagoon storage, or the ocean.

The percentage of sludges to be disposed of in each state that contained viable eggs of Ascaris, T. trichiura, T. vulpis or Toxocara are presented in Table 48. In samples from all four states, Toxocara eggs were found most frequently (55%), with Ascaris eggs, T. vulpis eggs, and T. trichiura eggs being found somewhat less frequently, 48%, 38% and 22% respectively. The mean numbers of eggs/kg dry weight of sludge of each of the four parasites found in these final sludges are also presented in Table 48. Ascaris eggs occurred in higher densities in final sludges than the other three parasites, and the numbers of Ascaris eggs in final sludges in Washington were significantly higher than in these sludges in the other three states.

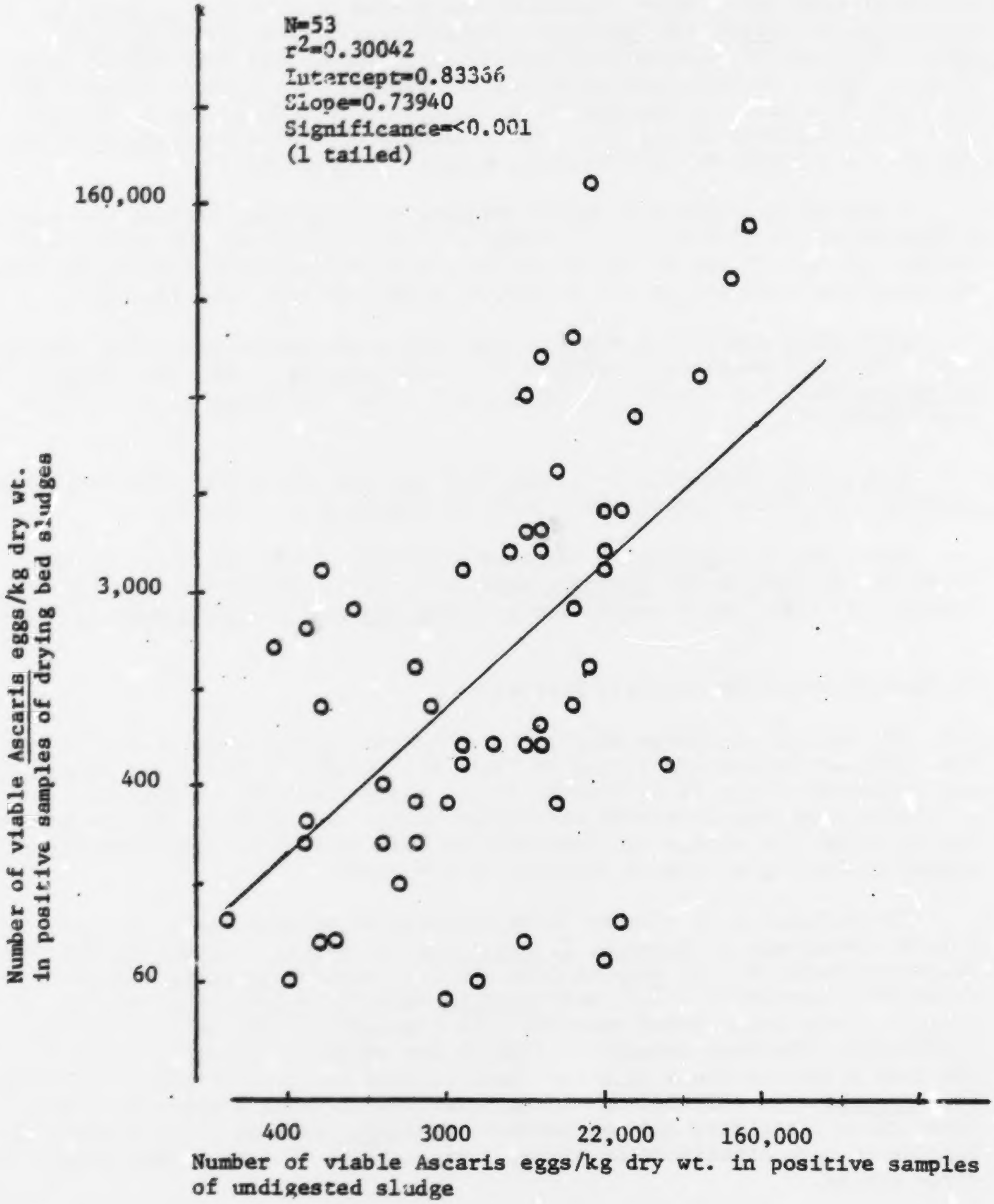


Figure 28. Viable Ascaris eggs in positive samples of undigested sludge vs. viable Ascaris eggs in positive samples of drying bed sludge: northern and southern combined.

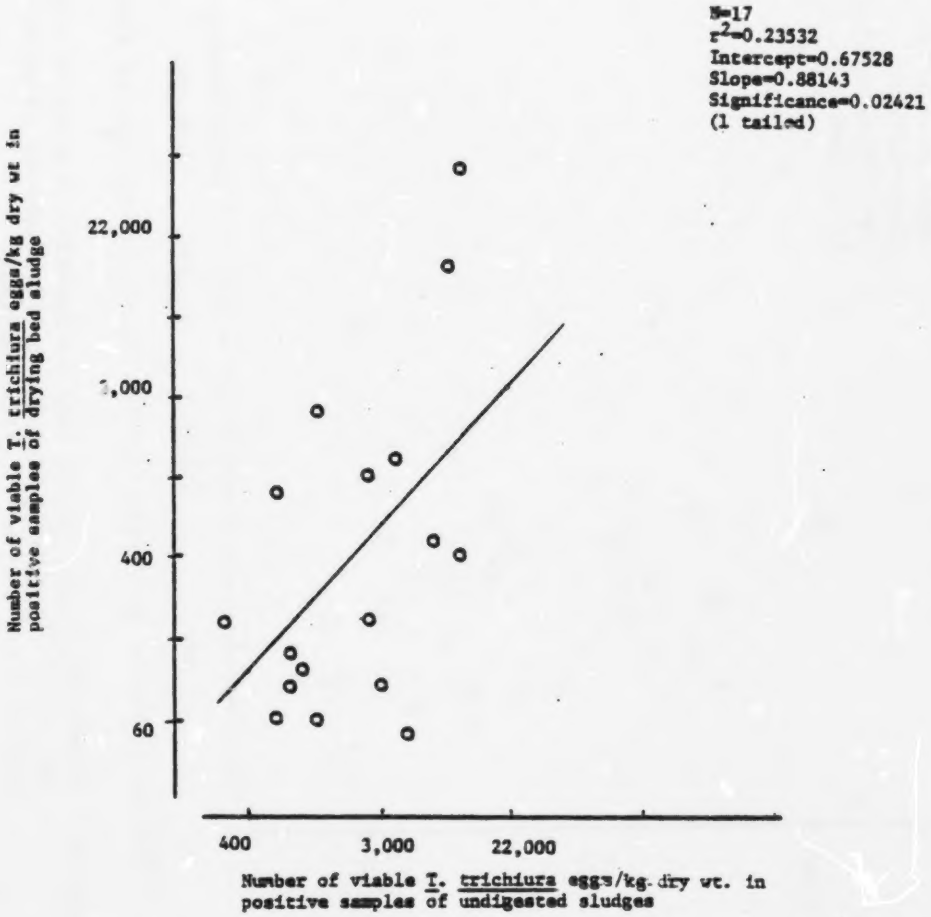


Figure 29: Viable *Trichuris trichiura* eggs in positive samples of undigested sludge vs. viable *T. trichiura* eggs in positive samples of drying bed sludge: northern and southern state combined.

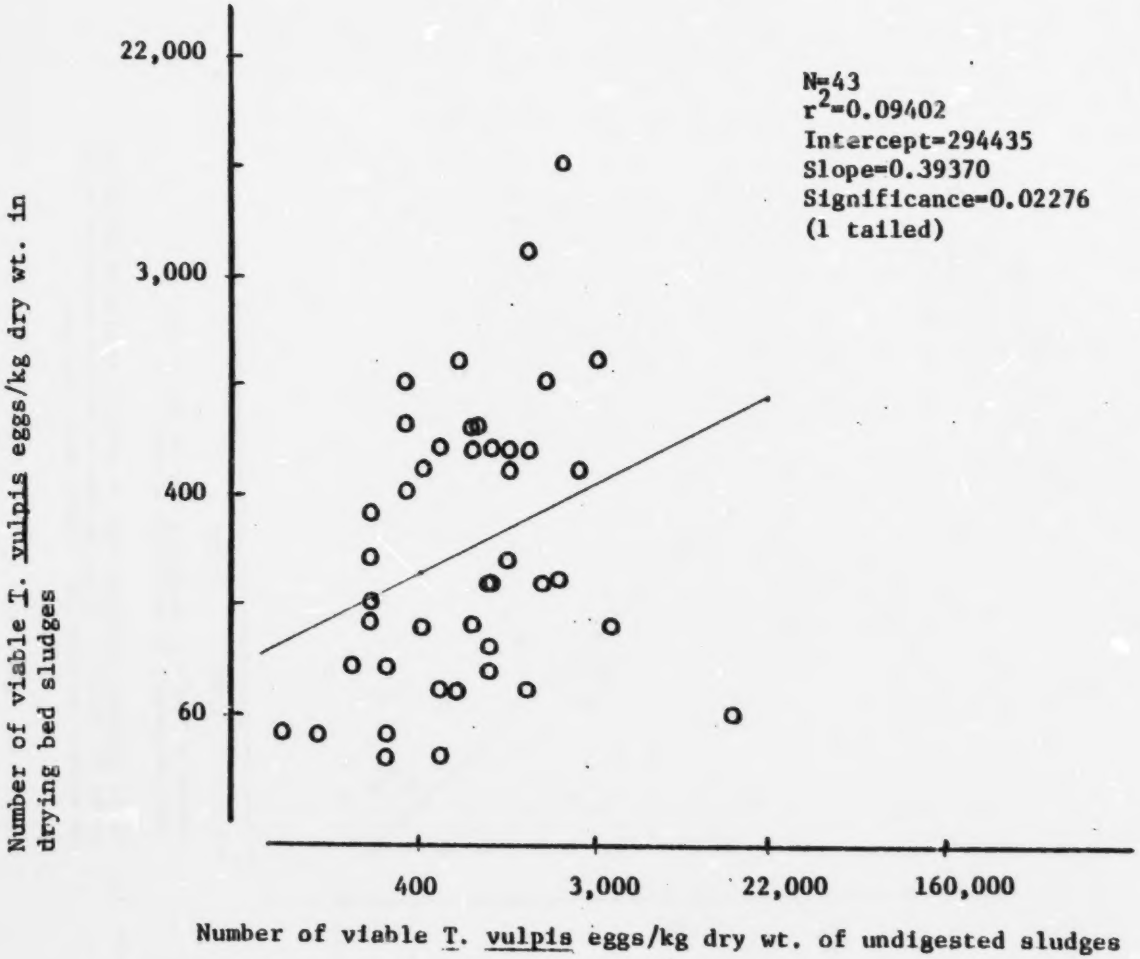


Figure 30: Viable *Trichuris vulpis* eggs in positive samples of undigested sludge vs. viable *T. vulpis* eggs in positive samples of drying bed sludge: northern and southern states combined.

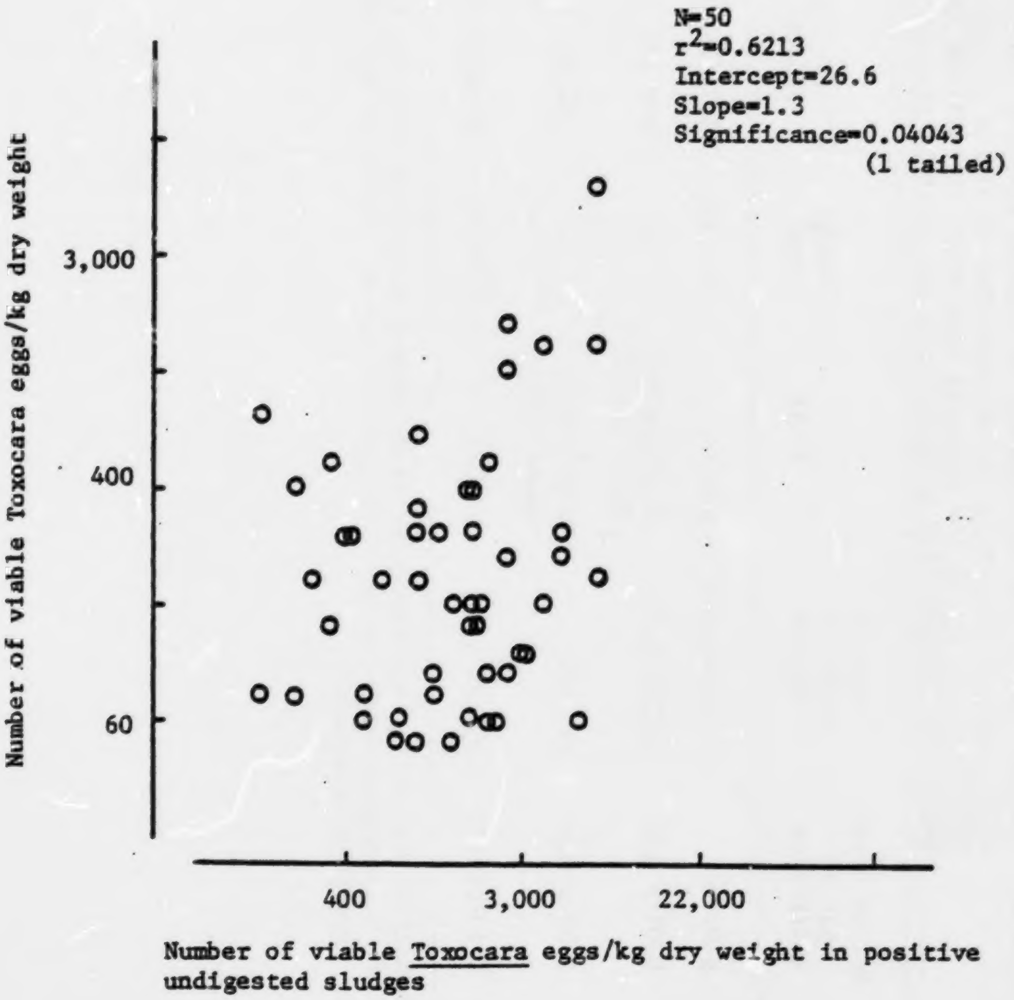


Figure 31. Viable Toxocara eggs in positive samples of undigested sludge vs. viable *Toxocara* eggs in positive samples of drying bed sludges: northern and southern states combined.

TABLE 46. SIGNIFICANCE OF THE RELATIONSHIP OF PERCENT MOISTURE CONTENT, REGION, SLUDGE AGE AND DIGESTION TO THE DENSITIES OF VIABLE *ASCARIS*, *TRICHURIS TRICHIURA*, *T. VULPIS* AND *TOXOCARA* EGGS FOUND IN POSITIVE SAMPLES OF DRYING BED SLUDGES FROM BOTH NORTHERN AND SOUTHERN STUDIES[1]

Parasite	No. of viable eggs in undigested	Percent moisture content	South	Sludge age	Digestion process	Season
Ascaris	$p<0.001$	$0.01>p>0.001$	$p>0.25$	$p>0.25$	$0.25>p>0.10$	$p>0.25$
T. trichiura	$0.05>p>0.01$	$0.05>p>0.01$	$0.01>p>0.001$ (more south)	--	$p>0.25$	$p>0.25$
T. vulpis	$0.05>p>0.01$	$p<0.001$	$0.05>p>0.01$ (more south)	--	$p>0.25$	$0.25>p>0.10$
Toxocara	$0.10>p>0.05$	$p<0.25$	$p>0.25$	$p>0.25$	$0.10>p>0.05$	$0.25>p>0.10$

---

[1] This is the probability that the listed parameter is by chance associated with the density level of parasite eggs. If the parameter was observed to be significant ($p \leq 0.05$) it was taken into account in the testing of subsequent parameters.

TABLE 47. METHODS OF SLUDGE DISPOSAL USED BY 48 TREATMENT PLANTS IN FOUR NORTHERN STATES

Method of disposal (type of sludge)	No. of plants[1]
Landfill (dewatered)	14
Landfill (liquid)	3
Fertilizing crops (dewatered)	9
Fertilizing crops (liquid)	7
Fertilizing pastures (dewatered)	3
Fertilizing pastures (liquid)	3
Public for home use (dewatered)	12
Commercial dealers (dewatered)	3
City parks, etc. (dewatered)	2
Dumped in ocean (liquid)	2
Lawns of commercial property (dewatered)	1
Golf courses (dewatered)	1
Land reclamation (dewatered)	1
Tree farms (dewatered)	1
Lagoon storage (liquid)	3

---

[1] Some plants used more than one method of disposal.

TABLE 48. PERCENTAGE OF SLUDGE SAMPLES DESTINED FOR DISPOSAL IN EACH OF FOUR NORTHERN STATES THAT CONTAINED VIABLE EGGS OF *ASCARIS*, *TRICHURIS TRICHIURA*, *T. VULPIS* AND *TOXOCARA* AND MEAN NUMBER OF EGGS OF EACH PARASITE

Eggs	STATE MN	OH	NY	WA	All Samples
Ascaris					
% Positive	29%	41%	49%	47%	48%
Geometric Mean[1]	375	235	560	1920	565
T. trichiura					
% Positive	14%	12%	31%	33%	22%
Geometric Mean	140	150	390	280	265
T. vulpis					
% Positive	12%	63%	56%	28%	38%
Geometric Mean	255	270	230	395	270
Toxocara					
% Positive	51%	68%	49%	50%	55%
Geometric Mean	315	280	455	515	370

---

[1] Expressed as number of eggs per killogram dry weight.

The number of treatment plants in each of the four states in which eggs of these four parasites were found in the final sludges, according to the season of sample collection, and the totals for all states are presented in Table 49.

The plants that distributed sludge to the public for use at home included 5 in Ohio, 4 in New York, 2 in Washington, and 1 in Minnesota. Viable eggs of *Ascaris*, *T. trichiura*, *T. vulpis* and *Toxocara* were found in 39%, 6%, 56% and 50%, respectively, of the samples of these sludges. The mean number of viable eggs of each of these parasites found in positive samples of these sludges was 492, 92, 300 and 580 eggs/kg dry weight, respectively.

Laboratory Studies

Aerobic Digestion--

In batch experiments, neither detention time nor the food to microorganisms ratio (F to M) appeared to affect the viability of *Ascaris* eggs (Table 50). Likewise, continuous aerobic digestion at 25°C with detention times of 10, 20 and 30 days did not noticeably affect these eggs (Tables 51-53). When continuous digestion was carried out at 35°C, there appeared to be a 30 to 50 percent inactivation of eggs within 10 days (Table 54). In the 35°C digesters, eggs were effectively killed within 7 days (Table 55); however, these results may be unreliable since a faulty temperature control mechanism was later found on this digester. The effect of temperature at 25 and 35°C on *Ascaris* eggs in these aerobic digesters with a 10-day detention time is shown in Figure 32.

Caustic and Lime Stabilization--

In batch studies, the addition of caustic (3200 mg NaOH/gram of suspended solids) to sludge from 25°C aerobic digesters had little effect on the viability of *Ascaris* eggs, even over a period of 10 days (Table 56, Figure 33). However, when the caustic was added to sludge from the 35°C aerobic digester, 97% of the eggs were killed within five days and 100% were killed within 10 days (Table 56, Figure 33).

In batch studies on lime stabilization of aerobically digested sludge, no inactivation of eggs was observed unless 1000 mg lime/gram of suspended solids was added. At that dosage, 97% of the eggs were killed within five days (Table 57, Figure 34).

Ammonification--

When ammonium sulfate was added to sludge at a dosage of 50 mg/gram of suspended solids that had been aerobically digested at 25°C (detention time of 10 days), there was little effect on *Ascaris* eggs during the first five days (Table 58). After 10 days, 62% of the eggs were inactivated when

TABLE 49. NUMBER OF TREATMENT PLANTS IN EACH NORTHERN STATE FROM WHICH EGGS OF **ASCARIS**, **TRICHURIS TRICHIURA**, **T. VULPIS** OR **TOXOCARA** WERE RECOVERED FROM A FINAL SLUDGE SAMPLE, ACCORDING TO TIME OF YEAR (SEASON) OF SAMPLE COLLECTION

State	No. of plants examined	FALL		WINTER		SUMMER		ALL COLLECTIONS	
		Total eggs	Viable eggs	Total eggs	Viable eggs	Total eggs	Viable eggs	Total eggs	Viable eggs
				ASCARIS					
MN	11	7	6	10	7	3	3	10	10
OH	12	8	6	5	4	5	5	9	7
NY	13	5	5	5	5	6	5	7	7
WA	12	6	6	7	7	5	5	8	8
				TRICHURIS TRICHIURA					
MN	11	2	1	4	1	2	2	6	4
OH	12	3	2	3	2	1	1	5	3
NY	13	7	4	4	4	6	4	7	5
WA	12	5	4	4	3	7	4	9	5
				TRICHURIS VULPIS					
MN	11	2	0	3	1	1	1	4	1
OH	12	7	7	8	8	7	6	9	9
NY	13	9	9	6	6	11	8	11	10
WA	12	3	3	5	5	3	3	7	6
				TOXOCARA					
MN	11	10	8	9	6	5	5	11	11
OH	12	9	9	8	8	8	6	9	9
NY	13	10	5	9	7	9	7	12	10
WA	12	6	6	8	8	5	4	9	9

TABLE 50. INACTIVATION OVER TIME OF ASCARIS EGGS IN BATCH AEROBICALLY DIGESTED SLUDGE

No. of days sludge digested prior to use	0	5	10	15
0	286/11.6/0[1]	368/14.6/(29)[2]	360/11.7/(26)	282/2.6/1
5	318/10.3/0	393/7.4/(24)	365/17.5/(15)	301/28.9/5
10	344/18.4/0	356/79.1/(3)	359/32.6/(4)	352/37.0/(2)

---

[1] Mean number of *Ascaris* eggs in 50 milliter samples/standard deviation/ percent inactivation (N=3).

[2] ( ) notes an increase in viable *Ascaris* eggs.

TABLE 51. INACTIVATION OVER TIME OF ASCARIS EGGS IN A CONTINUOUS AEROBIC DIGESTION PROCESS AT 25°C WITH A DETENTION TIME OF 10 DAYS[1]

Day of Sample	No. of Samples	Mean no. of viable eggs recovered (50ml sample)	Standard Deviation	Theoretical no. of viable eggs[2]	Percent inactivation of viable eggs[3]
0	3	475.0	22.1	475	—
2	2	446.5	79.9	380	(18)[4]
4	3	308.7	63.1	304	(2)
6	3	211.0	13.7	243	13
8	3	201.7	46.5	195	(14)
10[5]	3	144.0	15.6	156	7

---

[1] *Ascaris* eggs added at beginning of digestion period.

[2] Based on the 0 day sample.

[3] As compared to theoretical number of eggs present.

[4] ( ) notes percent increase.

[5] After day 10, sludge used in ammonification experiment.

TABLE 52. INACTIVATION OVER TIME OF *ASCARIS* EGGS IN A CONTINUOUS AEROBIC DIGESTION PROCESS AT 25°C WITH A DETENTION TIME OF 20 DAYS[1]

Day of sample	No. of sample	Mean no. of viable eggs recovered (50 ml sample)	Standard deviation	Theoretical no. of viable eggs[2]	Percent inactivation of viable eggs[3]
0	3	476.0	65.4	476	-
4	3	373.7	62.2	381	2
7	2	252.0	106.1	305	17
11	3	208.0	48.5	244	15
14	2	181.0	15.5	195	7
21[5]	3	157.7	9.5	156	(1)[4]

[1] *Ascaris* eggs added to aerobic sludge at beginning of digestion period.
[2] Based on the 0 day sample.
[3] As compared to theoretical number of viable eggs present.
[4] ( ) notes percent increase.
[5] After day 21, sludge used in ammonification experiment.

TABLE 53. INACTIVATION OVER TIME OF *ASCARIS* EGGS IN A CONTINUOUS AEROBIC DIGESTION PROCESS AT 25°C WITH A DETENTION TIME OF 30 DAYS[1]

Day of sample	No. of sample	Mean no. of viable eggs recovered (50 ml sample)	Standard deviation	Theoretical no. of viable eggs[2]	Percent inactivation of viable eggs[3]
0	3	556.3	87.0	556	—
4	3	347.7	74.9	501	31
7	3	518.0	49.5	451	(15)[4]
11	3	445.0	24.4	406	(10)
14	2	253.0	24.0	365	31
18	3	342.7	12.5	328	(4)
21	3	317.0	9.2	296	(7)
28	3	251.3	10.7	266	6
31[5]	3	201.0	23.5	239	16

[1] *Ascaris* eggs added to aerobic sludge at beginning of digestion period.
[2] Based on the 0 day sample.
[3] As compared to theoretical number of viable eggs present
[4] ( ) notes percent increase.
[5] After day 31, sludge used in ammonification experiment

TABLE 54. INACTIVATION OF ASCARIS EGGS IN A CONTINUING AEROBIC DIGESTION PROCESS AT 35°C WITH A DETENTION TIME OF 10 DAYS[1]

Day of sample	No. of sample	Mean no. of viable eggs recovered (50 ml sample)	Standard deviation	Theoretical no. of viable eggs[2]	Percent inactivation of viable eggs[3]
0	3	549.0	46.5	549	—
2	3	395.3	64.7	439	10
4	3	245.3	22.2	351	30
6	3	155.3	24.6	281	45
8	3	96.7	23.4	225	57
10[4]	3	126.3	44.4	180	30

---

[1] *Ascaris* eggs added to aerobic sludge at beginning of digestion period.
[2] Based on the 0 day sample.
[3] As compared to theoretical number of viable eggs present.
[4] After day 10, sludge used in ammonification experiment.

TABLE 55. INACTIVATION OVER TIME OF ASCARIS EGGS IN A CONTINUOUS AEROBIC DIGESTION PROCESS AT 35°C WITH A DETENTION TIME OF 20 DAYS[1]

Day of sample	No. of sample	Mean no. of viable eggs recovered (50 ml sample)	Standard deviation	Theoretical no. of viable eggs[2]	Percent inactivatin of viable eggs[3]
0	2	673.0	4.2	673	--
4	3	480.0	14.4	538	11
7	3	56.3	10.3	431	87[4]
11	3	34.7	12.0	344	90[4]
14	3	15.3	16.3	276	94[4]
21	3	21.7	4.5	221	90[4]

---

[1] *Ascaris* eggs added to aerobic sludge at beginning of digestion period.
[2] Based on the 0 day sample
[3] As compared to theoretical number of viable eggs present.
[4] The high rate of inactivation was reported due to a faulty temperature regulator.

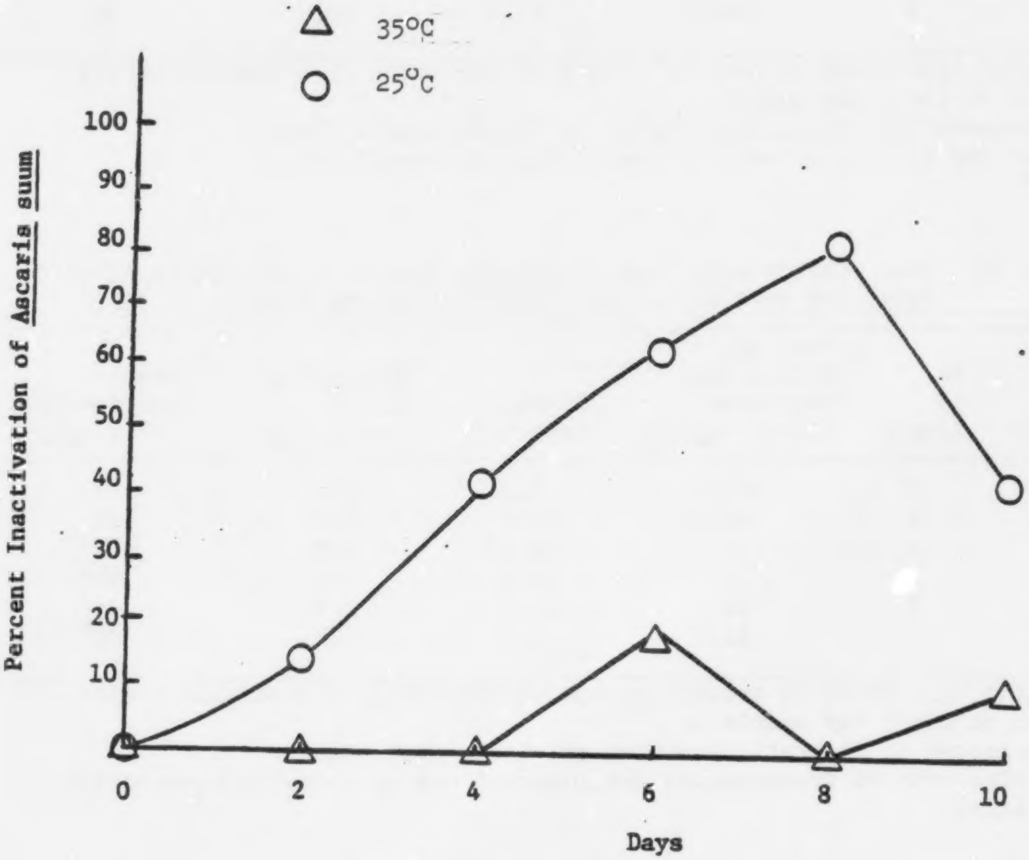


Figure 32. Inactivation over time of *Ascaris* eggs by aerobic digestion at different temperatures.

TABLE 56. INACTIVATION OVER TIME OF *ASCARIS* EGGS IN STABILIZED SLUDGE AFTER ADDITION OF CAUSTIC (3200 mg NaOH/g SUSPENDED SOLIDS)

Type of Sludge	NUMBER OF DAYS AFTER CAUSTIC ADDITION			
	0	2	5	10
25°C[1]				
Control	293/0[2]	295/(1)[3]	243/17	217/26
Caustic	267/0	276/(3)	224/16	175/34[4]
35°C[4] Control	79/0	88/(11)	96/(22)	89/(13)
Caustic	97/0	79/19	4/96	0/100

[1] Sludge from 25°C aerobic digester with 10-day detention time; *Ascaris* eggs added to digester 10 days prior to use.

[2] Mean number of viable *Ascaris* eggs recovered from 50 ml sample/percent inactivation (N=3).

[3] ( ) denotes percent increase in viable eggs.

[4] Sludge from 35°C aerobic digester with 10-day detention time, *Ascaris* eggs added to digester 10 days prior to use.

this dosage was used, but this was only slightly higher than the inactivation (41%) that occurred in the control sludge to which only caustic (NaOH) was added. When the ammonium sulfate dosage was 500 mg/gram of suspended solids, complete or nearly complete inactivation of eggs was observed after five days (Table 58, Figure 35).

When ammonium sulfate was added at a dosage range of 50 to 5,000 mg/g solids to sludge that had been aerobically digested at 35°C (detention time of 10 days), all, or nearly all, the eggs were inactivated within five days, however, it should be noted that 96% of the eggs in the control sludge to which only the caustic was added were inactivated in five days also. The results observed after five days when 500 mg ammonium sulfate/gram of suspended solids had been added to the aerobically digested sludge appear to be aberrant as shown in Table 59 and Figure 36.

When ammonia gas was added to sludges previously digested aerobically at 25°C (at detention times of 10, 20 or 30 days), a dosage of 1% was necessary to obtain effective inactivation of *Ascaris* eggs (Table 60, Figure 37). When the detention time of the digestion process at 25°C was 20 or 30 days, the *Ascaris* eggs appeared to be more susceptible to inactivation by ammonia than when the detention time was 10 days (Figures 38 and 39).

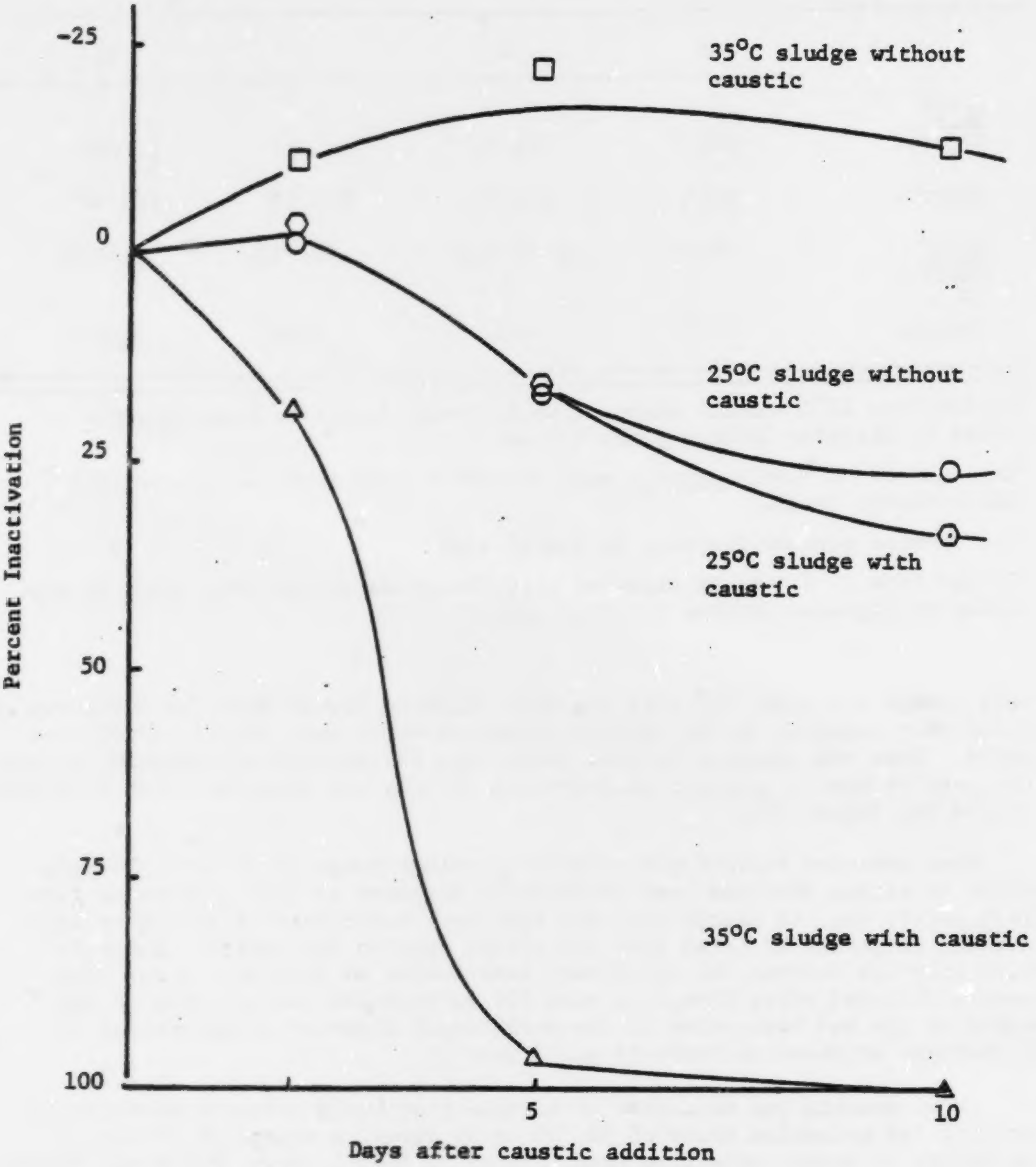


Figure 33: Inactivation over time of *Ascaris* eggs in stabilized sludge after addition of caustic (3200 mg NaOH/g of suspended solids).

TABLE 57. INACTIVATION OVER TIME OF ASCARIS EGGS IN BATCH AEROBIC SLUDGE DIGESTERS WITH DIFFERENT LIME DOSAGES RUN AT 25°C

Lime dosages of raw sludge	NUMBER OF DAYS AFTER LIME ADDITION				
	0	0.1	5	10	15
No lime	286/11.6/0[1]	-	368/17.6/(29)[2]	360/11.7/(26)	283/2.6/1
100mg lime/ℓ	267/20.0/0	157/72.0/72	285/66.0(7)	312/21.0/(17)	237/32.5/11
1000mg lime/ℓ	296/20.5/0	223/28.9/25	8/3.0/97	1/0.6/99.7	0/0/100

[1] Mean number of viable Ascaris eggs recovered from 50 ml sample/standard deviation/percent inactivation (N=3).

[2] ( ) notes percent increase of viable eggs.

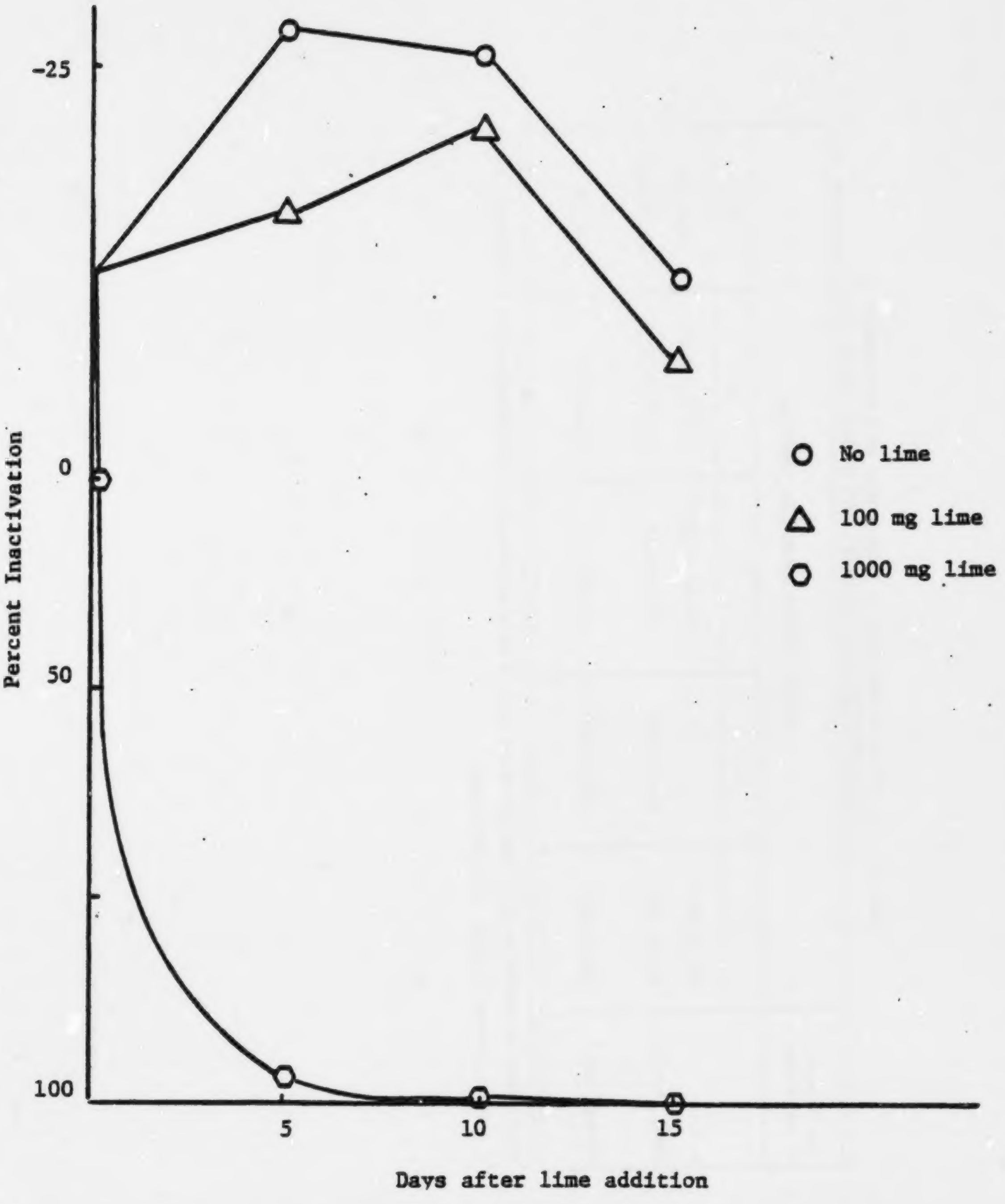


Figure 34. Inactivation over time of Ascaris eggs in batch aerobic sludge digesters with different lime dosages run at 25°C.

TABLE 58. INACTIVATION OVER TIME OF *ASCARIS* EGGS IN SLUDGE PREVIOUSLY DIGESTED AEROBICALLY (25°C AND 10-DAY DETENTION TIME) AFTER THE ADDITION OF DIFFERENT AMMONIUM SULFATE DOSAGES (3200 mg CAUSTIC (N_2OH)/g OF SUSPENDED SOLIDS ADDED TO ASSURE AMMONIA SPECIES)

TREATMENT		NUMBER OF DAYS AFTER AMMONIUM SULFATE ADDITION							
C or L[1]	Mg/g of S.S. of $(NH_4)_2SO_4$ as NH_3	0		2		5		10	
		Viable eggs[2]	Percent inactivated[3]	Viable eggs[2]	Percent inactivated[3]	Viable eggs[2]	Percent inactivated[3]	Viable eggs[2]	Percent inactivated[3]
None	0	293	0	295	(1)[4]	243	17	217	26
C	0	267	0	276	(4)	224	2	125	41
C	50	346	0	306	12	254	14	76	62
C	500	264	0	93	65	10	95	0	100
C	5,000	143	0	0	100	0	100	0	100
L	5,000	99	0	1	99	0	100	0	100
C	10,000	205	0	39	81	9	95	0.3	99
C	10,000[5]	137	0	84	39	0	100	0	100
C	10,000[6]	177	0	0.3	99	0	100	0	100

[1] C=3,000 mg NaOH/g dry solids.
L=3,000 mg lime/g dry solids.

[2] Mean number of viable Ascaris eggs recovered from 50 ml sample (n=3).

[3] Inactivation as compared to controls that had no caustic, lime or $(NH_4)_2SO_4$ added.

[4] ( ) notes percent increase.

[5] 20-day detention time for aerobic digestion of sludge used before ammonification.

[6] 30-day detention time for aerobic digestion of sludge used before ammonification.

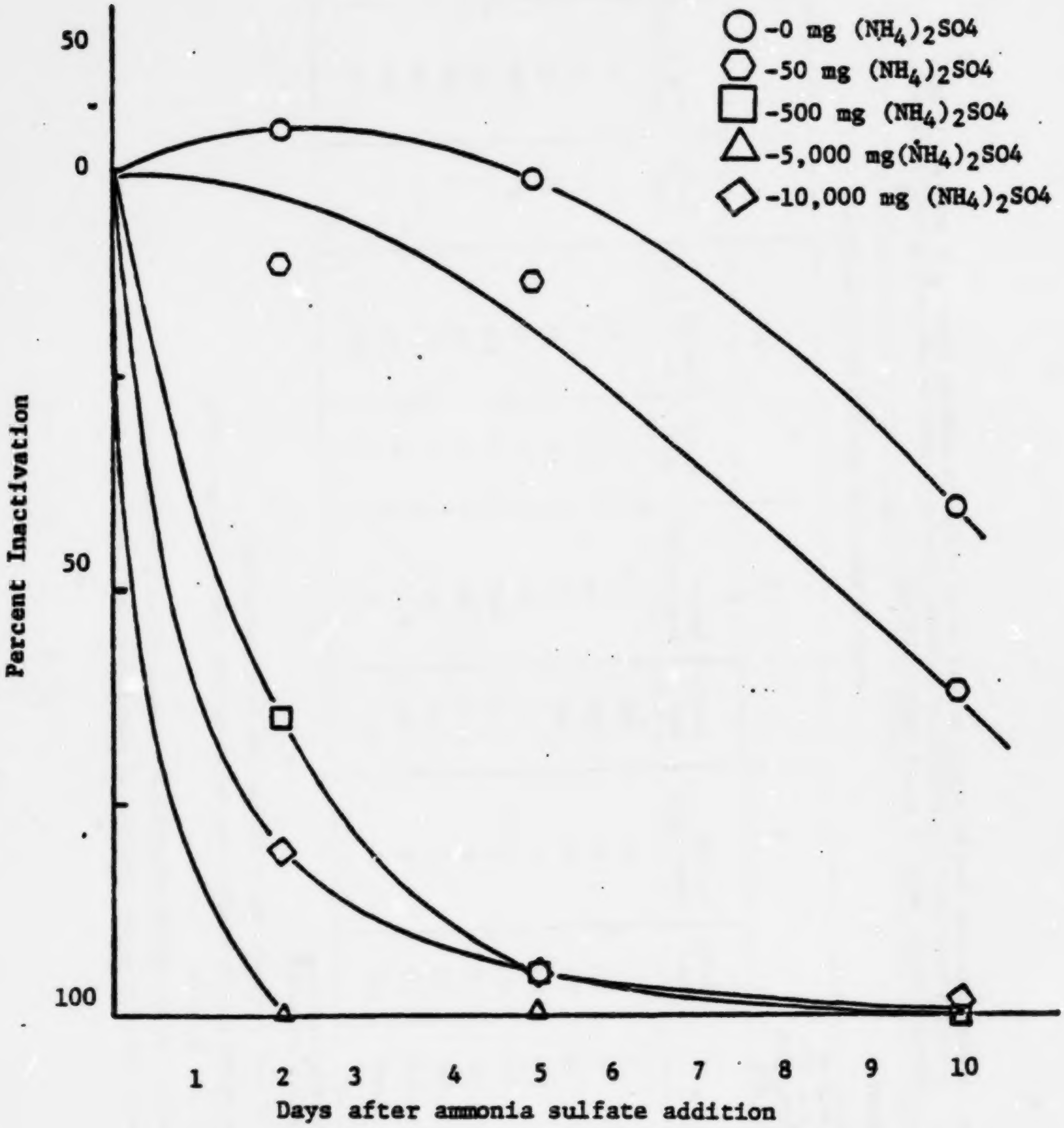


Figure 35. Inactivation over time of *Ascaris* eggs in sludge previously digested aerobically (25°C and 10 days detention time) after addition of 3200 mg NaOH per g of suspended solids and with varied ammonia dosages.

TABLE 59. INACTIVATION OVER TIME OF ASCARIS EGGS IN SLUDGE PREVIOUSLY DIGESTED AEROBICALLY (35°C AND 10-DAY DETENTION TIME) AFTER THE ADDITION OF DIFFERENT AMMONIUM SULFATE DOSAGES (3200 mg CAUSTIC (NaOH)/g OF SUSPENDED SOLIDS OR 3,000 mg LIME/g OF SUSPENDED SOLIDS ADDED TO ASSURE AMMONIA SPECIES)

TREATMENT		NUMBER OF DAYS AFTER AMMONIUM SULFATE ADDITION							
C or L[1]	Mg/g of S.S. of $(NH_4)_2SO_4$ as NH_3	0		2		5		10	
		Viable eggs[2]	Percent inactivated[3]	Viable eggs[2]	Percent inactivated[3]	Viable eggs[2]	Percent inactivated[3]	Viable eggs[2]	Percent inactivated[3]
None	0	79	0	88	(11)[4]	96	(22)	89	(13)
C	0	97	0	79	19	4	96	0	100
C	50	111	0	66	41	4	97	0	100
C	500	108	0	89	18	46	57	0	100
C	5,000	42	0	0	100	0	100	0	100
L	5,000	60	0	0	100	0	100	0	100
C	10,000	188	0	19	90	0.3	99	0	100
C	10,000[5]	22	0	1	95	0.7	97	0	100

[1] C=3200 mg NaOH/g of solids.
L=3000 mg lime/g of solids.

[2] Mean number of viable Ascaris eggs recovered from 50 ml samples (n=3).

[3] Inactivation as compared to controls that had no caustic, lime or $(NA_4)_2SO_4$ added.

[4] ( ) notes percent increase.

[5] 20-day detention time in aerobic digester before treatment.

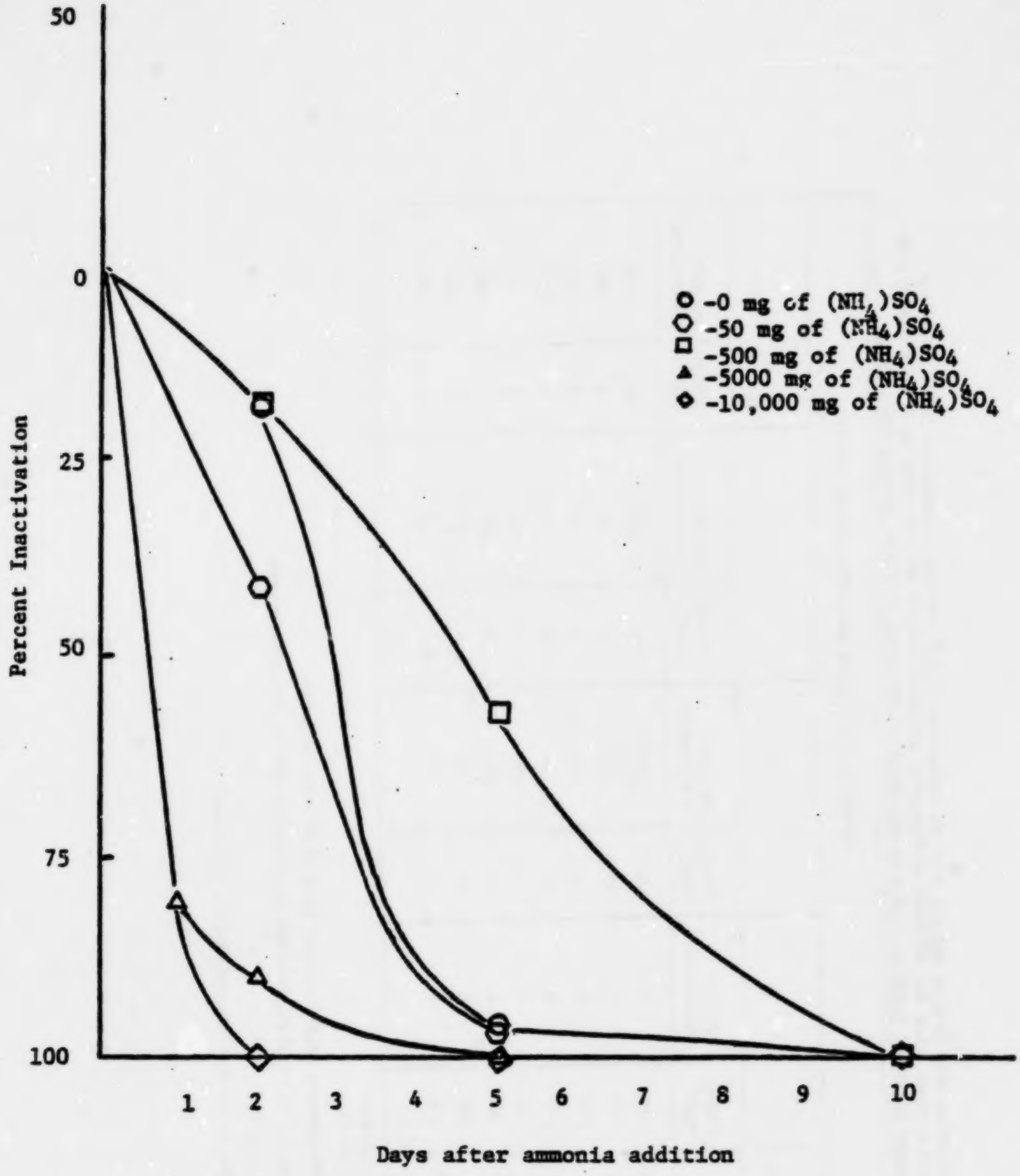


Figure 36: Inactivation over time of Ascaris eggs in sludge previously digested aerobically (35°C and 10 days detention time) after addition of 3200 mg NaOH per g of suspended solids and with varied ammonia dosages.

TABLE 60. INACTIVATION OVER TIME OF *ASCARIS* EGGS AFTER THE ADDITION OF DIFFERENT DOSAGES OF AMMONIA IN SLUDGES PREVIOUSLY DIGESTED ANAEROBICALLY AT 25°C WITH 10, 20 OR 30-DAY DETENTION TIME

Percent of[1] ammonia observed	NUMBER OF DAYS AFTER AMMONIA ADDITION				
	0	1	2	5	10
	10-DAY DETENTION TIME				
0	197/76/0[2]	145/2/22	131/20/20	108/26/42	135/16/28
0.1	198/10/0	167/2/16	150/12/24	71/43/64	121/10/29
0.5	138/—/0	123/-/11	—	72/43/64	53/—/62
1.0	217/8/0	120/21/45	49/11/77	42/12/81	15/10/93
4.0	220/6/0	0.3/0.6/99	0/0/100	0/0/100	0/0/100
	20-DAY DETENTION TIME				
0	158/13/0	153/9/3	173/70/(9)[3]	168/12/(6)	154/12/3
0.1	147/30/0	145/20/1	—	107/24/27	54/11/63
3.0	133/11/0	0.3/0.6/99	0/0/100	0/0/100	0/0/100
4.0	163/8/0	0/0/100	0/0/100	0/0/100	0/0/100
	30-DAY DETENTION TIME				
0	160/0/0	173/20/(8)	161/13/(1)	168/17/(5)	150/9/6
0.1	152/21/0	144/9/5	170/23/21	144/26/5	102/17/33
1.0	179/18/0	15/7/92	2/2/99	0/0/100	0/0/100
4.0	160/22/0	0/0/100	0/0/100	0/0/100	0/0/100

[1] One percent ammonia = 10,000 mg/kg suspended solids.

[2] Mean number of viable *Ascaris* eggs recovered from 50 milliter samples/standard deviation/percent inactivation n=3).

[3] ( ) notes percent increase.

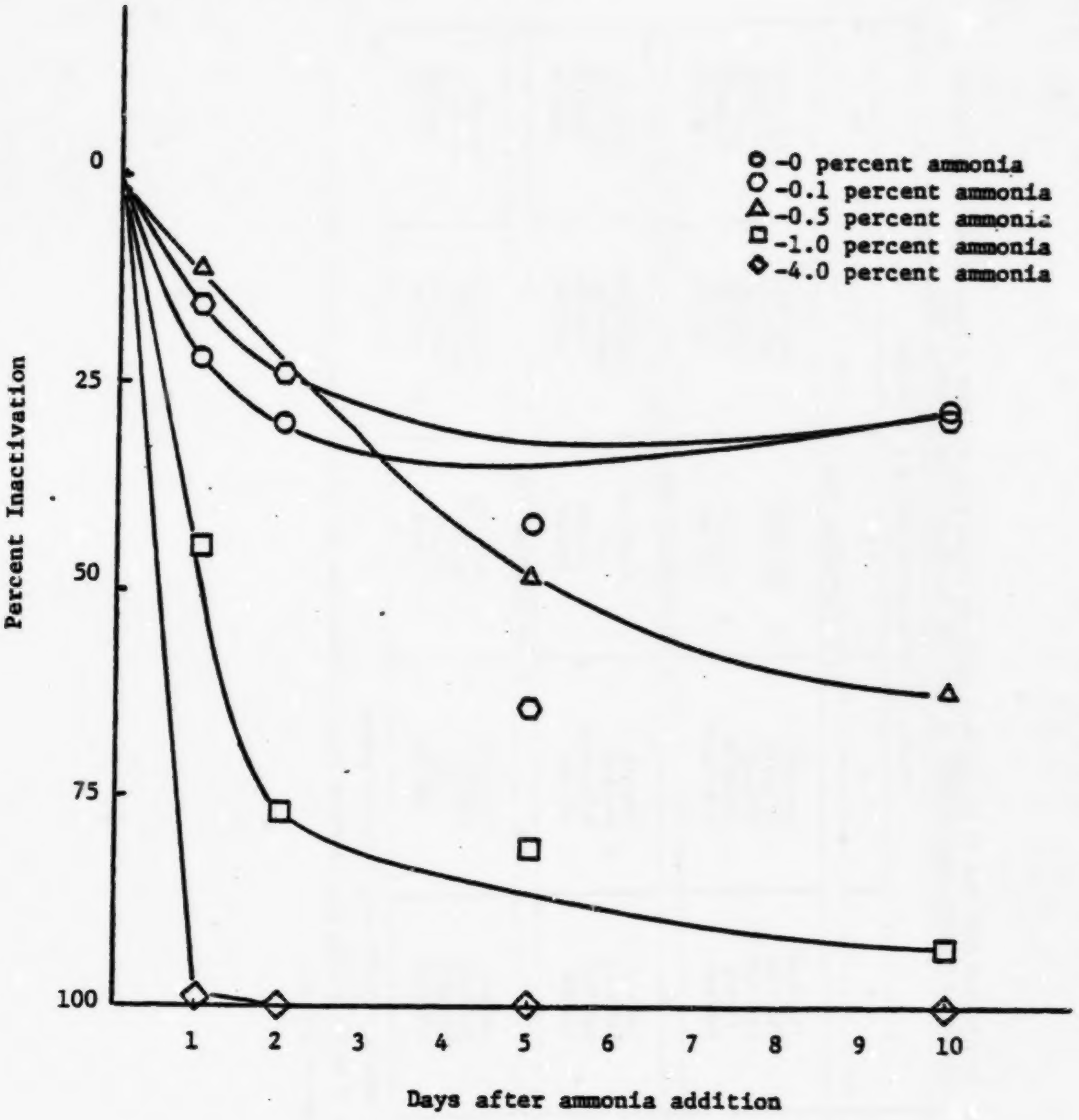


Figure 37: Inactivation over time of Ascaris eggs after different ammonia dosages were added to sludge previously digested aerobically (25^oC and 10 days detention time).

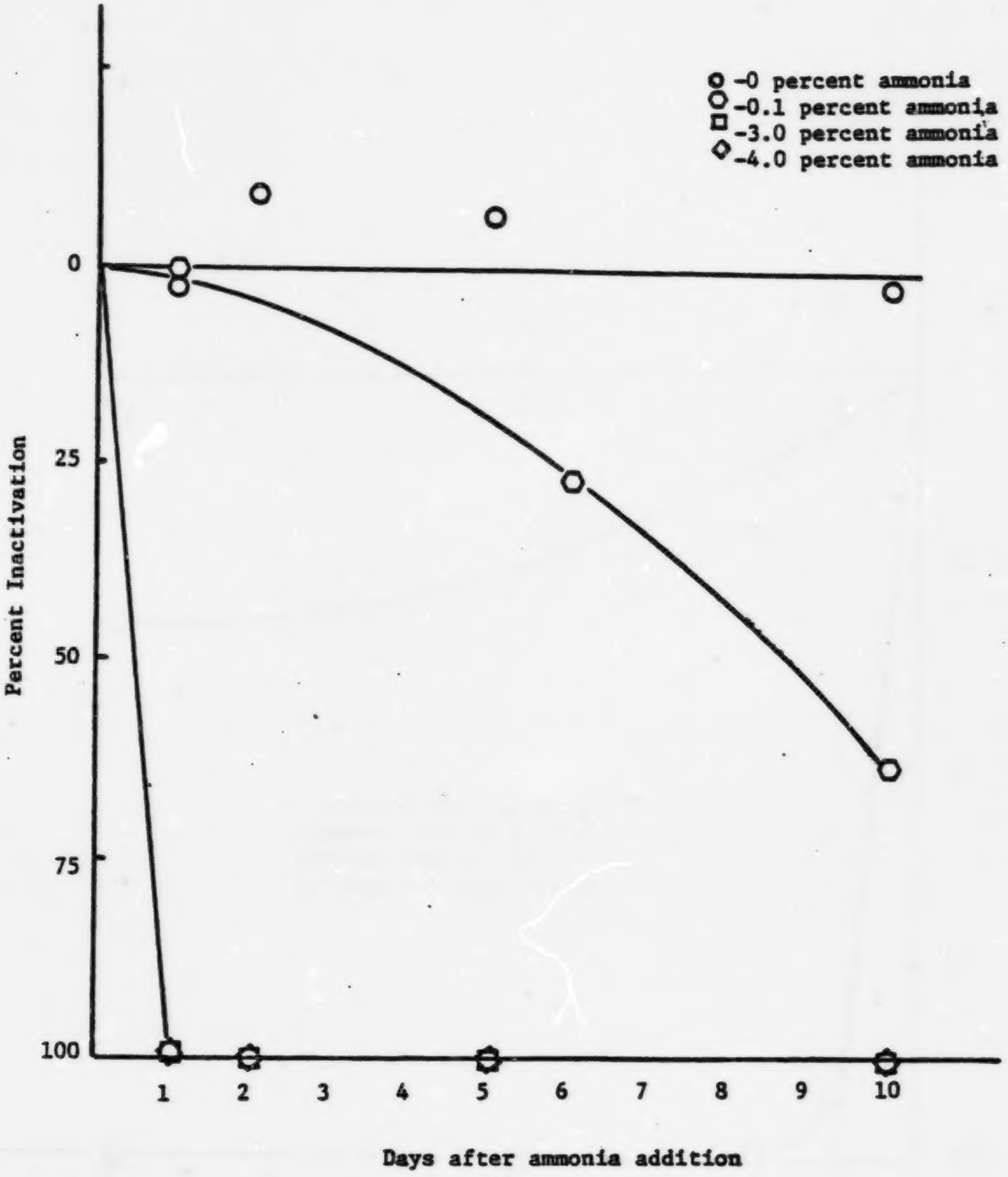


Figure 38: Inactivation over time of *Ascaris* eggs after different ammonia dosages were added to sludge previously digested aerobically (25°C and 20 days detention time).

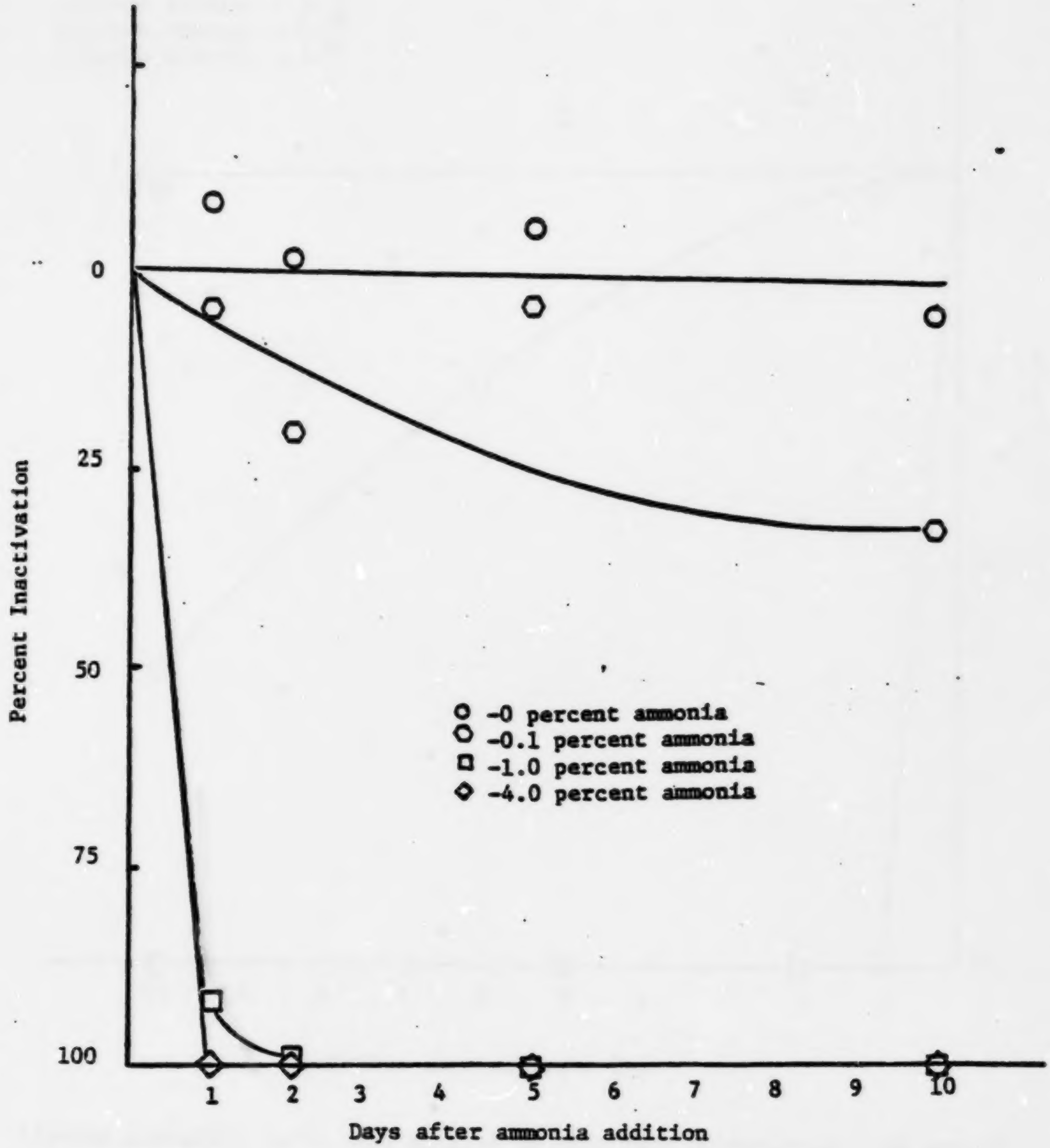


Figure 39. Inactivation over time of Ascaris eggs after different ammonia dosages were added to sludge previously digested aerobically (25°C and 30 days detention time).

When ammonia gas was added to sludges digested at 35°C, a greater degree of inactivation as compared to the 25°C sludge, was seen with the respecive dosages (Table 61, Figure 40). With the 35°C sludges, little difference was noted with respect to detention time (Figure 41).

Ultrasonication—

When *Ascaris* eggs were exposed to an ultrasonic field at 33 kHz and 600 watts for 60 minutes, 90 to 92% were inactivated (Table 62). Since this exposure time was inordinately long, shorter exposure times were studies at exposure times of 2.2, 4.6, 7.4 and 10.7 minutes, the inactivation (average) was 18, 40, 63 and 77 percent, respectively (Table 63, Figure 42).

Irradiation with Cobalt 60—

When sludges containing viable *Ascaris* eggs were exposed to gamma irradiation (Co^{60}), it was found that dosages of 200 krads or greater were completely effective in killing the eggs (Table 64). *Ascaris* eggs from the feces of pigs and from the uteri of worms were equally susceptible to the irradiation as were intact and decoated eggs.

DISCUSSION

Field Studies

Parasitologic Findings—

The probable identities of each of the 20 types of parasite eggs and cysts found in the sludges from four northern states are shown in Table 65. The most commonly found stages were the eggs of *Ascaris* spp., *Trichuris trichiura*, *T. vulpis* and *Toxocara* spp. The eggs of one or more of these four parasites were found in 89% of all samples examined (viable eggs in 82%). The eggs of these four parasites were also the most commonly found ones in our previous study of sludges in five southern states (11), the only other comprehensive study of parasites in sludges in the United States. In the southern study, eggs of one or more of these four parasites were found in 95% of all samples examined (viable eggs in 85%).

In the northern states, *Toxocara* was the most frequently found parasite with eggs being found in 79% of the samples (viable eggs in 69%) (Table 66). *Ascaris* was the second most frequently found parasite with eggs being found in 54% of all samples (viable eggs in 48%). However, in the southern study, *Ascaris* was the most frequently found parasite with eggs being found in 81% of the samples (viable eggs 74%). *Toxocara* eggs were found in 75% of all southern samples (viable eggs in 63%).

As can be seen in Table 66, *T. vulpis* and *T. trichiura* eggs were found less frequently than *Ascaris* and *Toxocara* eggs in both the north and the south. While *T. trichiura* eggs were found in nearly the same percentage of

TABLE 61. INACTIVATION OVER TIME OF *ASCARIS* EGGS AFTER THE ADDITION OF DIFFERENT DOSAGES OF AMMONIA IN SLUDGE PREVIOUSLY DIGESTED AEROBICALLY AT 35°C WITH 10 OR 20 DAYS DETENTION TIME

Percent of ammonia observed[1]	NUMBER OF DAYS AFTER AMMONIA ADDITION				
	0	1	2	5	10
			10-DAY DETENTION TIME		
0	135/27/0[2]	155/9/0	159/24/(3)[3]	161/38/(4)	193/27/(25)
0.1	177/14/0	191/49/(8)	201/39/(14)	187/28/(6)	156/23/12
0.5	55/-/0	—	27/-/51	27/-/51	17/-/69
1.0	164/33/0	21/3/97	9/3/95	7/5/96	1/0/99
4.0	154/15/0	0/0/100	0/0/100	0/0/100	0/0/100
			20-DAY DETENTION TIME		
0	24/3/0	24/3/0	17/7/29	27/0/(13)	27/8/(13)
0.1	19/6/0	11/4/42	10/10/47	17/3/11	16/3/16
1.0	17/4/0	8/6/53	3/2/82	1/1/96	0/0/100
4.0	17/5/0	0/0/100	0/0/100	0/0/100	0/0/100

[1] Percent ammonia = 1,000 mg/kg suspended solids.

[2] Mean number of viable Ascaris eggs recovered from 50 milliter samples/standard deviation/percent inactivation (n=3).

[3] ( ) notes percent increase.

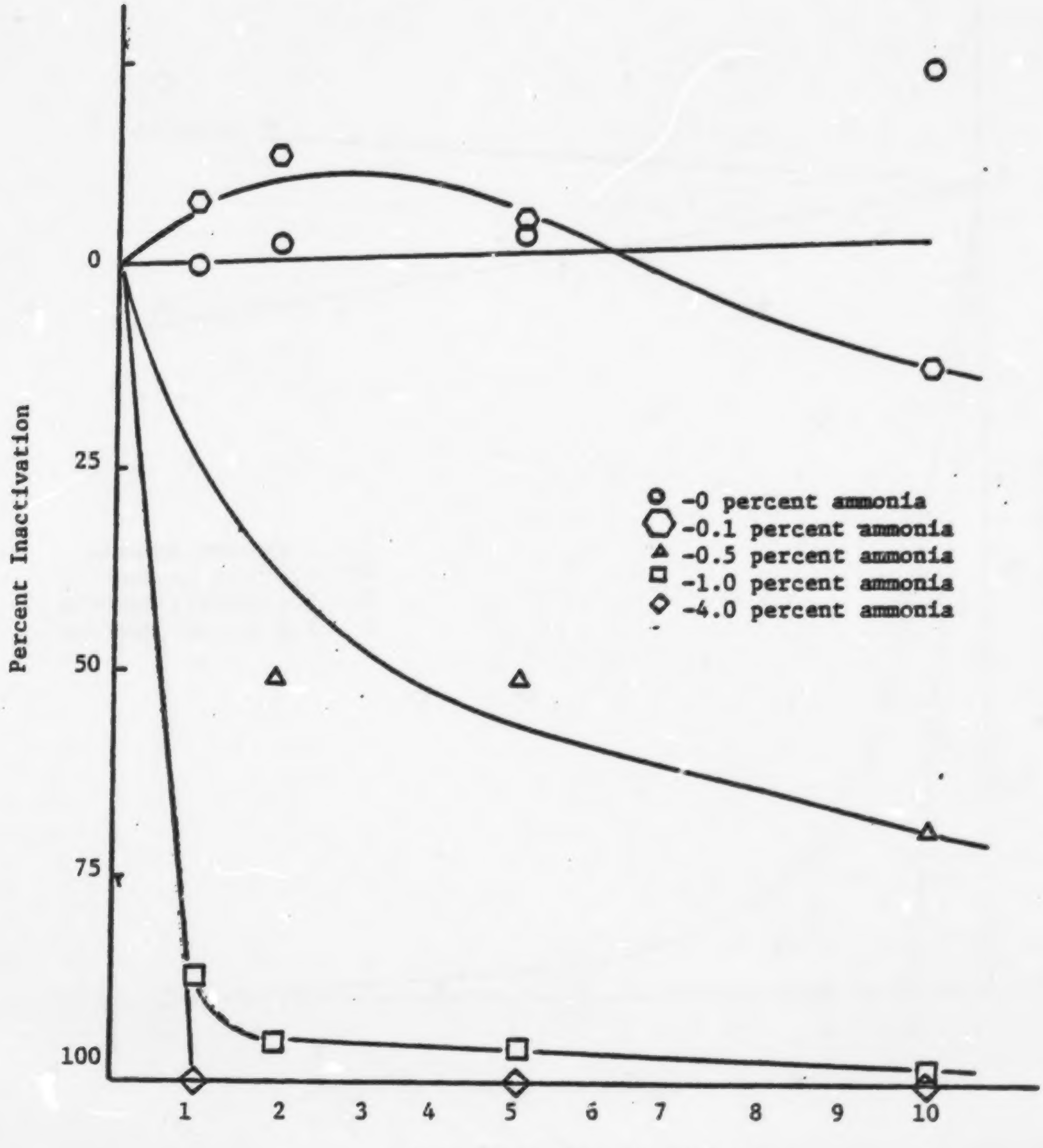


Figure 40: Inactivation over time of *Ascaris* eggs after different ammonia dosages were added to sludge previously digested aerobically (35°C and 10 days detention time).

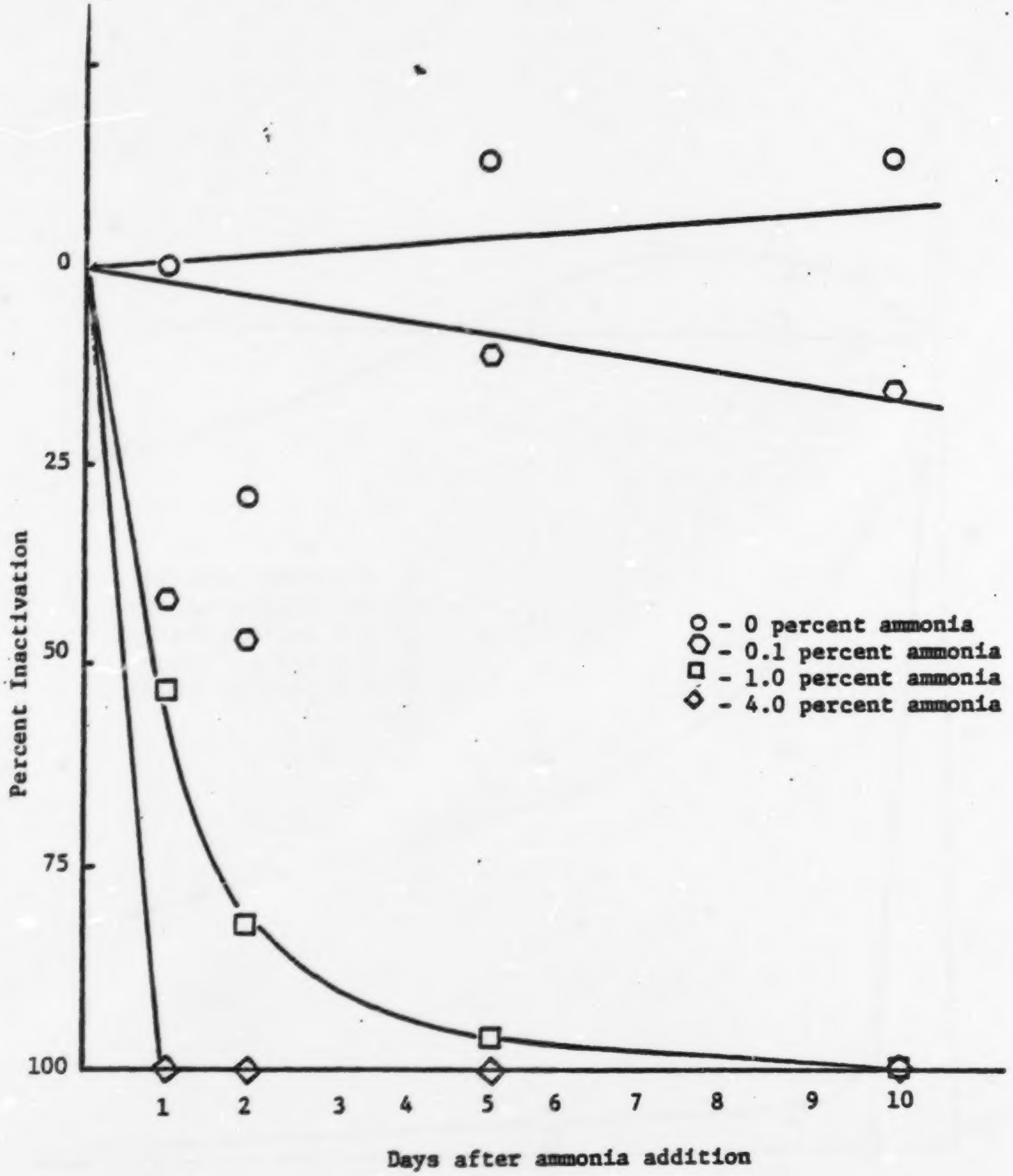


Figure 41: Inactivation over time of Ascaris eggs after different ammonia dosages were added to sludge previously digested aerobically (35°C and 20 days detention time).

TABLE 62. EFFECTS OF EXPOSURE OF *ASCARIS* EGGS TO AN ULTRASONIC FIELD OF 33 kHz AND 600 WATTS FOR 60 MINUTES

	Viable (with (motile larva) (50 ml samples)	Non-viable (undeveloped) (50 ml samples)	Percent viable	Percent inactivation
Test 1	32	426	7	92
Control 1	380	17	96	—
Test 2	31	393	7	92
Control 2	406	18	96	—
Test 3	43	438	9	90
Control 3	242	37	92	—

TABLE 63. RESULTS OF EXPOSURE FOR DIFFERENT PERIODS OF TIME OF *ASCARIS* EGGS TO AN ULTRASONIC FIELD OF 33 kHz AND 600 WATTS

Sample	Viable *Ascaris* Eggs (50 ml samples)	Nonviable *Ascaris* eggs (50 ml samples)	Percent viable	Percent inactivation	Exposure time[1]
OA	459	14	97	0	0.0
OB	499	14	97	0	0.0
15A	434	121	78	19	2.2
15B	432	101	81	16	2.2
30A	317	231	58	39	4.6
30B	330	249	57	40	4.6
45A	165	324	34	63	7.4
45B	199	385	34	63	7.4
60A	106	436	20	77	10.7
60B	199	459	20	77	10.7

[1] Conversion of clock time to ultrasonication time.

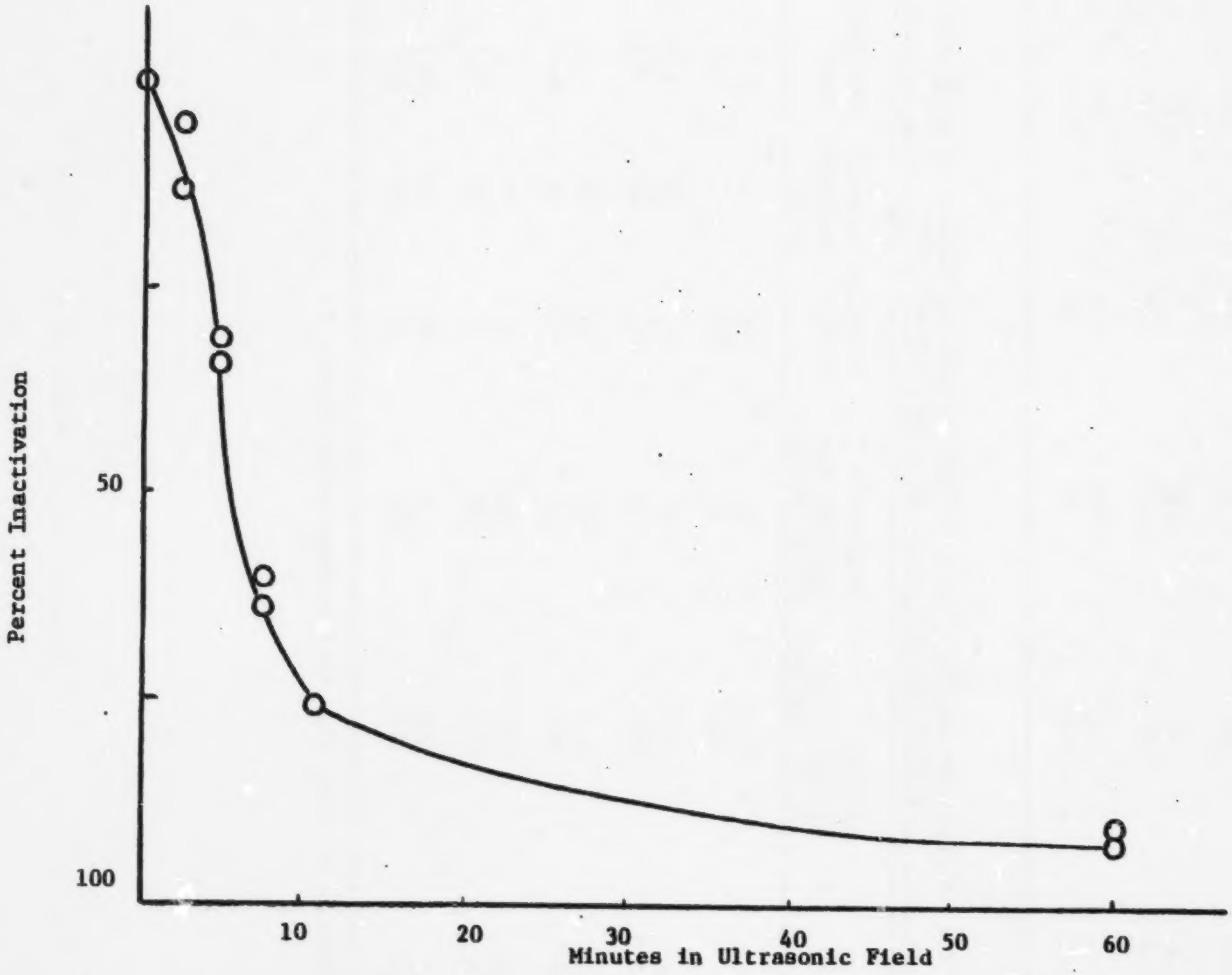


Figure 42. Inactivation of *Ascaris* eggs exposed to an ultrasonic field of 33 kHz and 600 watt field for different periods of time.

TABLE 64. SUMMARY OF RESULTS OF EXPOSURE OF INTACT AND DECOATED *ASCARIS SUUM* EGGS IN SLUDGE (3% SOLIDS) TO VARYING DOSES OF GAMMA RADIATION, CO^{60} SOURCE (DOUBLE-BLIND STUDY)

Dose (krads)		Intact eggs from pig feces	Decoated eggs from pig feces	Decoated eggs from uteri of worms
0	No. eggs observed[1]	158	128[2]	252
	No. embryonated eggs[1]	156	106	239
	Percent viable	98.7	82.8	94.8
50	No. eggs observed	182	206	198
	No. embryonated eggs	98	93	131
	Percent viable	53.8	45.1	66.2
100	No. eggs observed	223	215	198
	No. embryonated eggs	17	7	11
	Percent viable	7.6	3.3	4.8
200	No. eggs observed	186	209	204
	No. embryonated eggs	0	0	0
	Percent viable	0	0	0
400	No. eggs observed	176	191	271
	No. embryonated eggs	0	0	0
	Percent viable	0	0	0
1000	No. eggs observed	136	186	199
	No. embryonated eggs	0	0	0
	Percent viable	0	0	0

[1] Each observation based on sum of four replicate samples of 10 ml each.

[2] Based on three replicate samples, one sample destroyed by mold.

TABLE 65. PROBABLE IDENTITY OF PARASITES FOUND IN SLUDGE SAMPLES FROM 48 WASTEWATER TREATMENT PLANTS IN FOUR NORTHERN STATES

Parasite found	Probable identity	Definitive host(s)
Ascaris eggs	*Ascaris* lumbricoides[1]	Man
	Ascaris suum	Pigs
Toxocara eggs	*Toxocara canis*[2]	Dogs
	Toxocara cati[2]	Cats
Trichuris trichiura eggs	*Trichuris trichiura*	Man
	Trichuris suis	Pigs
Trichuris vulpis eggs	*Trichuris vulpis*	Dogs
Toxascaris leonina eggs	*Toxascaris leonina*	Dogs and cats
Ascaridia-like eggs	*Ascaridia galli*	Domestic poultry
	Heterakis gallinae	Domestic poultry
Parascaris equorum	*Parascaris equorum*	Horses
Trichosomoides-like eggs	*Trichosomoides crassicauda*	Rats
	Anatrichosoma buccalis	Opossums
Capillaria spp. eggs (3 or more types, some with pitted shells and some with striated shells)	*Capillaria hepatica*	Rats
	Capillaria gastrica	Rats
	Capillaria plica	Cats and dogs
	Capillari spp.	Domestic poultry
	Capillaria spp.	Wild birds
	Capillaria spp.	Wild mammals - opossums, racoons, etc.
Gongylonema-like eggs	*Gongylonema neoplasticum*	Rats
	Gongylonema spp.	Domestic and wild animals
Physaloptera-like eggs	*Physaloptera* spp.	Cats and dogs
	Turgida spp.	Opossums, etc.
Schistosoma mansoni eggs	*Schistosoma mansoni*	Man
Hymenolepis diminuta eggs	*Hymenolepis diminuta*	Rats
Hymenolepis nana-like eggs	*Hymenolepis nana*	Man
	Hymenolepis fraterna	Rodents

(continued)

TABLE 65. (Continued)

Parasite found	Probable identity	Definitive host(s)
Diphyllobothrium latum-like eggs	*Diphyllobothrium latum*	Man, dogs, bears
Spirometra-like eggs	*Spirometra mansonoides*	Cats and dogs
Entamoeba coli-like cysts	*Entamoeba coli*[4]	Man
	Entamoeba spp.	Rodents, etc.
Giardia cysts	*Giardia lamblia*	Man
	Giardia spp.	Dogs, cats, mammals
Coccidia oocysts	*Isopora* spp.	Dogs and cats
	Sarcocystic spp.	Dogs and cats
	Eimeria spp.	Domestic and wild birds, mammals

---

[1] Eggs of *A. lumbricoides* and *A. suum* are indistinguishable.

[2] *Toxocara* were probably mostly *T. canis*.

[3] *T. suis* eggs were probably seldomly seen.

[4] An intestinal amoeba that is a commensal, not a parasite.

TABLE 66. PERCENTAGE OF SLUDGE SAMPLES FROM FOUR NORTHERN STATES AND FROM FIVE SOUTHERN STATES THAT CONTAINED EGGS OF *ASCARIS* SPP., *TRICHURIS TRICHIURA*, *T. VULPIS* AND *TOXOCARA* SPP. AND THE MEAN NUMBER OF TOTAL AND VIABLE EGGS OF EACH PARASITE RECOVERED

EGGS	*ASCARIS*	*T. TRICHIURA*	*T. VULPIS*	*TOXOCARA*
NORTH				
Total				
% Positive	54%	36%	42%	79%
Mean No.[1]	1900	380	290	1400
Viable				
% Positive	48%	25%	37%	69%
Mean No.[1]	1400	200	260	1100
SOUTH				
Total				
% Positive	81%	45%	71%	75%
Mean No.[1]	2800	910	470	790
Viable				
% Positive	74%	25%	61%	63%
Mean No.[1]	2500	880	430	680

---

[1] Number of eggs per kilogram of dry weight of sludge sample.

the sludges in the north and south, *T. vulpis* eggs were found much more frequently in the south than in the north.

In addition to finding a higher percentage of the sludge samples in the southern than in the northern states that contained eggs of *Ascaris*, *T. trichiura*, and *T. vulpis*, the mean number of eggs of each parasite in sludge samples was also higher in the southern sludges. In the case of *Toxocara*, not only was the percentage of sludge samples containing eggs higher in the north than the south, but the mean number of eggs in northern samples was nearly double that found in southern samples.

The reason why *Toxocara* differs in this regard from the three other parasites is not clear. However, it would appear that either the prevalence of *T. canis* in dogs is higher in northern than in southern states or that worm burdens in dogs are higher in northern states. If either or both of these possibilities are true it would indicate that the factors affecting the transmission of *Toxocara* are somewhat different from those affecting the transmission of *Ascaris*, *T. trichiura* and *T. vulpis*.

As mentioned in our earlier report (11), the eggs of *Ascaris lumbricoides*, the human roundworm, and *A. suum*, the pig roundworm, are indistinguishable, and, consequently, it is not possible to know the true prevalence of the eggs of each of these parasites in the sludges examined in the north and south. However, it seems that *A. suum* eggs were unlikely to have been present except in sludges from those plants that received wastes from meat packing plants or abattoirs. From a public health point of view, both parasites are important since *A. suum* can produce disease in humans and domestic animals as well as in pigs (11,12).

The *Toxocara* eggs observed in the sludges were judged to be mostly those of *T. canis*, the roundworm of dogs, and relatively few of them to be *T. cati*, the roundworm of cats. Both parasites have been reported to produce disease in humans, but it is generally acknowledged that *T. canis* is responsible for many more cases of human infection in the form of visceral larva migrans.

The eggs of *Trichuris trichiura*, the human whipworm, and *T. suis*, the pig whipworm, are also nearly identical, and it is not possible to know the true prevalence of each in the sludges from the four northern states. However, as in the case of *A. suum*, it is unlikely that the eggs of *T. suis* were present to any significant degree unless a plant received wastes from a meat packing plant or an abattoir. Disease in humans due to *T. suis* is unknown but one successful experimental infection has been reported (50).

Trichuris vulpis, the whipworm of dogs, is not known to produce disease in man although several human infections have been reported (51).

Of the 16 other types of parasites found in northern sludges, only a few are known to produce infections in man. *Schistosoma mansoni*, the human blood fluke, is a major cause of parasitic disease of man in Africa and parts of South America. In this study a single egg was found in a sample from a plant in New York. Undoubtedly, this egg came from a person that had acquired the infection elsewhere, possibly Puerto Rico. This egg was dead and it is unlikely that the eggs of S. mansoni would be able to survive in sludge after passage through a wastewater treatment plant.

Hymenolepis diminuta is a natural parasite of rats, but human infections with this parasite are occasionally reported. The eggs are not directly infective to man but must undergo development in an insect before they are infective for man or rodent. They do not survive well in sludge. The occurrence of these eggs in sludge is probably the result of rodents living in or near the sewage system.

Hymenolepis nana is the dwarf tapeworm of man and infections are occasionally found in this country. The eggs of H. fraterna, a closely related parasite of rodents, are indistinguishable from those of H. nana. Consequently, the H. nana-like eggs found in this study could belong to either parasite. In any case, viable eggs were never found in samples of treated sludge.

Diphyllobothrium latum is a large tapeworm that infects man, dogs, and bears. Two intermediate hosts are required in its life cycle, a copepod and a fish, and the freshly passed eggs must reach clear, cool water before they are able to develop to the stage that infects the first intermediate host. In the United States, it is restricted to the northern states where clear, cool freshwater lakes occur. All of the eggs observed in this study appeared to be dead and it is unlikely that these eggs would be able to retain their viability while passing through a treatment plant. These eggs were found in sludges in 36 samples from 9 plants in Minnesota, Ohio and New York. It is surprising that they were found this frequently since the parasite is generally regarded to occur infrequently in animals and man in northern United States. The source of these eggs is unknown but it seems likely that they are mainly from infected dogs since human cases are rarely reported. This is a very large tapeworm and one worm can produce about one million eggs each day. Consequently, if the feces from a few infected animals enter a sewage system, they may contribute enough eggs that they can subsequently be detected in a relatively small sample of the sludge from this plant.

Although Spirometra does not infect humans as adult worms, a larval stage of this worm does occasionally produce sparganosis in man. Humans acquire infections by drinking water containing infected copepods, the first intermediate host, or by ingesting the uncooked flesh of frogs or small mammals that contain a larval stage of this parasite called the sparganum. The life cycle of Spirometra is similar to that of D. latum and it is unlikely that its eggs can survive passage through a sludge treatment process.

While Taenia eggs were found in sludge from one plant in the southern study, none were found in sludges from the north. Human infections with Taenia saginata or T. solium are rarely observed in the United States; however, dogs and cats in this country are commonly infected with Taenia taeniaeformis and T. pisiformis, respectively. David and Linquist (52) recently reported that the specific gravity of Taenia eggs is about 1.225. Since the $ZnSO_4$ flotation solution used in the parasitologic analysis of sludge in this and the previous study has a specific gravity of 1.200, it seems likely that Taenia eggs could have been present in some of the sludge samples, but were not detected. Of the eggs tested for specific gravity by David and Lindquist, the only other eggs having a specific gravity greater than 1.200 were those of Physaloptera sp. Nevertheless, Physaloptera-like eggs were found on one occasion in the present study.

Although Giardia and some of the coccidia observed in the study are potentially infective for man, viable cysts of these protozoa were never observed in samples of treated sludges.

Undigested and Digester Sludges—

The finding of relationships between the densities of different parasite eggs in sludges and the population served by treatment plants is interesting but the reason for these relationships is not always clear. In some cases they may be due to the variable nature of the sludge samples obtained or to the techniques used for analysis, but in other cases they are undoubtedly due to other factors. For example, fewer eggs of Toxocara and T. vulpis were found in undigested sludges from plants serving large populations than from plants serving small populations, while the densities of Ascaris and T. trichiura in undigested sludges were not related to plant size. The lower densities of Toxocara and T. vulpis, primarily parasites of dogs, in the larger plants may be due to higher rates of infection or higher worm burdens in dogs in small rural towns than in dogs in larger cities. It is also possible that in the larger cities there are fewer dogs per capita. In large cities, dogs are more likely to be confined indoors which would lessen their chances of infection with these soil-transmitted parasites. Also, in many large cities, there are separate systems for storm water and for sewages so that fewer eggs of Toxocara and T. vulpis would enter a treatment plant via surface water from streets and yards.

The finding of greater densities of Ascaris and T. trichiura eggs in sludges from digesters from plants serving large populations than from plants serving smaller populations may be due to several reasons. Since humans are the primary source of these eggs in sludges, it might indicate that the prevalence of these infections is greater in larger cities than in smaller communities. In many of the northern states, poor people and refugees and immigrants from endemic areas, groups that often have higher rates of parasitic infections, are more likely to be located in large cities.

It is difficult to compare the densities of eggs of Ascaris, Trichuris and Toxocara in undigested sludges to those in sludges from digesters because the levels in undigested sludges are likely to fluctuate to a greater degree than in sludges from digesters.

As noted in the earlier study (11), parasite eggs in digesters tend to become evenly dispersed (equalized) due to the continual mixing of new sludge with old sludge during the detention period. In essence, samples from digesters are 20 to 30-day composite samples. Also, digesters tend to concentrate the heavier parasite eggs in relation to the solid content of the sludge since solids are continually degrading while relatively few of the parasites are lost. The finding of greater densities of Ascaris and

Toxocara eggs in digester sludges than in undigested sludges may be due to this reason. Why slightly fewer T. trichiura and T. vulpis eggs were found in digester sludges than in undigested sludges is not clear.

While one plant treating hog processing wastes in the southern states was found to contain extremely high densities of Ascaris eggs, no such counterpart was found in the north. Overall, the treatment of hog or meat processing wastes was not associated with significant increased densities of Ascaris eggs in sludges. Although slightly higher densities of Ascaris eggs were observed in plants in Minnesota receiving hog or meat processing wastes.

While significantly more samples were positive for Ascaris when meat treatment wastes were present, the presence of meat processing wastes was associated with decreased densities of eggs in sludges. This may be due to the proportion of meat treatment waste handled in relation to the whole sewage load. Meat treatment wastes would not be expected to contain Toxocara or T. vulpis eggs, and when these wastes were present, these wastes could dilute the density of the Toxocara and T. vulpis eggs present from other sources. This was also apparently the case with T. trichiura eggs in which the egg densities were greater when meat processing wastes were absent.

Generally speaking, the states of New York and Washington had higher densities of Ascaris, T. trichiura, T. vulpis and Toxocara than did Minnesota and Ohio. The relatively high densities of Ascaris eggs found in Washington sludges were perhaps due to the large number of migrant workers in the state picking the fruit and vegetable crops. The damp climate may also be a contributing factor.

Significantly higher densities of eggs of Ascaris, T. trichiura and T. vulpis were found in southern sludges than in those from the north (Table 66). This probably is due to the fact that the climate in southern states is more condusive to parasite transmission. The cooler temperatures in the north are known to adversely affect the transmission of soil-transmitted parasites and the long periods of the year when cold temperatures completely prevent transmission.

The mean densities of Toxocara eggs were higher in the northern sludges than in the southern sludges but the differences were not significant. This may be due to the fact that the Toxocara life cycle is less dependent upon outside environmental factors for transmission (53).

While no significant differences in total egg densities were found between anaerobic and aerobic sludges, fewer viable Ascaris and Toxocara eggs were found in anaerobic sludges than in aerobic sludges. This may be due to the increased temperature at which anaerobic digestion takes place (generally 35-40°C) while aerobic digestion occurs at a much lower temperature (generally ambient). The detention time in an anaerobic system may be up to 60 days, especially if a secondary digester is employed so a longer contact time at a higher temperature could be responsible for this phenomenon. Laboratory studies have indicated a 40% reduction at 35°C and a 100% reduction of viable Ascaris and Toxocara eggs after 4 days of anaerobic digestion at 45°C (11).

Stabilized Sludges--

The Zimpro process, which utilizes heat and pressure for sludge treatment was totally effective in inactivating parasite eggs. Only one dead Ascaris egg was ever found in this treated sludge, although numerous viable eggs were found in pre-treatment samples. It is doubtful that this type of treatment will be most cost-effective for parasite inactivation, though, due to the high energy and capital costs of such a system.

A plant that composted stored primary sludge appeared to do an effective job in inactivating parasite eggs, as no eggs were ever recovered from the composted sludge during the three trips, although eggs were present at low levels in the undigested sludge. This inactivation may reflect a 100% kill and destruction of the eggs by the heat generated by the composting action. It is also quite possible that composting reduced the densities of viable eggs not only through the heat but also by the dilution effect of adding wood chips to the sludge.

One plant processed vegetable wastes, and thus found it necessary to lime its undigested sludge before sending it to a lagoon. The lime dose was quite low, (< 100 mg/kg of dry suspended solids) and this did not appear to have a marked effect on the densities of viable Ascaris and T. trichiura. No viable Toxocara eggs were ever recovered from the lagoons, although they were present in 2 of the 3 undigested sludge samples. Laboratory studies indicate that lime may be effective in reducing the viability of Ascaris eggs at doses as low as 100 mg lime/g suspended solids for anaerobically digested sludges (11).

Data from two Minnesota lagoons storing anaerobically digested sludge indicates no effect in parasite egg inactivation during the winter months, although it is possible that some inactivation is occurring during the summer months. Due to the limited data and reduction in solids during sludge treatment, these observations are not statistically significant, but indicate a need for further study to investigate the effects and mechanisms of lagoon storage on parasite egg inactivation with respect to temperature and sludge residence time.

Previous findings indicate possible inactivation of parasite eggs when moisture levels of drying bed sludges fall below 20%. For this reason, plants in the north were selected to include more drying bed samples than were actually representative. The moisture contents of drying bed sludges in the north were generally too high for effective kill, and were much higher than those found in the south. This may be due to a decrease in solar radiation with increased latitude which would result in less heating of the sludge and therefore reduce drying. Plots of the densities of viable eggs in drying bed sludges vs percent moisture of that sludge show a significant relationship, however, similar to that previously reported for drying beds in the southern states, except that temperatures were not as high and moisture contents not as low as were seen in the south.

Regression analysis indicates that in the northern states, percent moisture content of the sludge was not a significant factor affecting the viability of Ascaris, although it was for Toxocara. This may be due to the relatively high moisture contents encountered in northern drying bed sludges and a higher resistance to desiccation of Ascaris over Toxocara. Toxocara appears also to be more susceptible to the effects of anaerobic digestion. Although there was observed to be decreasing densities of viable parasite eggs with decreasing moisture content of drying bed sludges, it would appear that moisture content was not the only factor causing this phenomenon, since it is unlikely that eggs would die from desiccation at the moisture levels observed, i.e., 20 percent and above. Future studies are planned to determine what other factors may play a role in inactivating eggs in drying bed sludges.

Final Sludges--

In the early 1970's, an EPA report indicated that over 60 percent of all sludges produced by wastewater treatment plants in Ohio were utilized as soil amenders in agricultural settings (54). It was also noted that in many cases this application had been occurring for over fifty years. In the present study, it was found that final sludges from 66 percent of the municipal plants studied in New York, Ohio, Minnesota and Washington were being applied to the land. These two observations indicate that the land application of municipal sludges is probably more widespread than generally recognized.

In the present study, viable eggs of Ascaris and Toxocara were found in approximately 50 percent of the final sludges examined, and at significant levels. The mean numbers of viable eggs of Ascaris and Toxocara found in positive final sludge samples were 565 and 370 per kilogram dry weight, respectively (Table 48). In the state of Washington, the mean number of viable Ascaris eggs in positive final sludge samples was even higher, 1920 per kilogram dry weight. Viable Trichuris trichiura eggs were found in 22 percent of the final sludges in the four states and the mean number found was 265 per kilogram of solids..

From reports in the literature and the results of this study it would appear that eggs of human and animal parasites occur in domestic sewage in relatively high densities and that they are not adversely affected by conventional sludge stabilization processes. Once these sludges are applied to the land, the viable helminth eggs may develop to the infective stage and pose a potential health threat to man and animals. At present, little information is available on the survival of these parasite eggs in various field situations, yet the scant information that exists suggests that the more resistant eggs, such as Ascaris, may survive from weeks to years. However, field studies on the survival of these eggs following the land application of sludges are lacking.

Since viable eggs of Ascaris and Toxocara are probably present in the majority of sludges being applied to the land in the United States, several questions need to be resolved before the potential health problems associated with this use of sludges can be evaluated and steps taken to minimize the risks. The following problems need to be addressed:

1. The survival of resistant stages of parasites, i.e., Ascaris eggs, in the soil after the land application of municipal sludges is presently unknown and needs to be studied.

2. The effects of various factors including; method of sludge application, soil type, climate, land usage, sludge treatment, etc., on parasite survival need to be evaluated.

3. Following the above studies, the degree of risk to humans and animals should be determined with respect to different field situations, i.e., type of sludge and method of application, intended land use, climate, etc.

After the above studies are completed, a rational management and sludge treatment scheme can be developed. These plans should consider proper inactivation techniques, safety of people in contact with sludge before and after land application, and crop and livestock control.

Laboratory Studies

Introduction—

The literature and recent research studies indicate that several domestic waste treatment processes are capable of either removing or inactivating eggs of parasites as shown in Table 7. The effectiveness of these processes varies considerably depending upon the type of waste, climate, parasite, etc.

Laboratory studies on select wastewater sludges were conducted to determine factors involved in the inactivation of parasite eggs in sewage sludge. Bench scale results of continuous aerobic sludge digestion, lime or caustic stabilization, ammonification, sonication, gamma irradiation, and combinations of the above processes for the destruction of *Ascaris suum* eggs in sludges are discussed in the following sections.

Aerobic digestion was chosen for study since it is the most effective standard sludge stabilization process for inactivating parasite eggs. The application of lime stabilization is generally expensive, but in applying sludge to the land as soil amender, many sludges will tend to make soils too acidic so liming will be required at the application point anyway. Likewise, ammonification is an expensive technique in the inactivation of pathogens, but because sludges are generally low in nitrogen, the addition of 1 to 3 percent nitrogen may be necessary for proper nutrient levels at the site. Therefore, the application of lime and ammonia after the drying bed and/or stabilization process could be utilized for a triple purpose (stabilization, pathogenic inactivation, and fertilizer input). Finally, the irradiation and ultrasonic treatment are two unique processes which could inactivate parasites with no change for existing technology if their design can be properly optimized (i.e., cost).

Aerobic Digestion--

Recent studies have found that aerobic digestion enhances the inactivation of parasite eggs in subsequent treatment procedures (11, 55, 56). Black et al. (55) noted aerobic and anaerobic digestion inactivated Ascaris suum eggs by 36% and 23%, respectively. This difference in inactivation was found to be statistically significant. Higher rates of inactivation were also noted for aerobic digestion by Reyes et al. (56). In this study, sludge age appeared to have no influence on the inactivation of Ascaris eggs by aerobic digestion, yet the temperature appeared to inactivate Ascaris suum eggs even at mesophilic range (approximately 35°C). In our first study, the eggs were not cultured. Therefore, eggs that were observed to be viable visually might have been found to be nonviable if they had been cultured. An important observation of this study shows the influence of further treatment after aerobic digestion in the inactivation of Ascaris eggs at mesophilic temperatures. The inactivation of Ascaris eggs is greatly enhanced with caustic stabilization and ammonification after mesophilic digestion. This enhancement of inactivation will be elucidated in later sections.

Lime and Caustic Stabilization--

Since lime stabilization has been successful in the inactivation of bacterial and viral pathogens, the potential of lime stabilization to inactivate parasites was investigated. From the field studies in the northern part of the United States, lime stabilization appeared to be ineffective in the inactivation of Ascaris and many other helminth eggs. This ineffectiveness was thought to be due to the low lime dosages used in the field (< 100 mg/kg of sludge dry weight).

In previous studies at Tulane (11), lime stabilization produced noticeable reduction in the viability of Ascaris eggs. Under aerobic conditions at ambient temperatures with dosages of 1,000 mg or greater of lime per gram of dry sludge solids, the viability of Ascaris eggs was observed to be reduced over 80% within five days in primary, 28°C aerobically digested or 35°C aerobically digested sludges. Under anaerobic conditions at ambient temperatures with lime dosages of 100 mg of lime per gram of dry sludge solids, a 100% reduction of viable Ascaris eggs was noted within 20 days in 28° aerobically digested sludge. The effectiveness of lime stabilization is a function of the biodegradation rate which produces organic acids and carbonic acid (carbon dioxide). Since the degradation rate is greater under aerobic conditions than anaerobic conditions, the quantity of lime required to inactivate Ascaris eggs increased since more lime was required to neutralize the excess acid and to hold the sludge pH to 11.5 or greater.

In our recent lime stabilization studies (11), the limed aerobically digested sludges were aerated, these conditions representing a worst case situation. In this study, the Ascaris eggs recovered were cultured instead of using the less accurate visual method determining viability. All samples were analyzed in triplicate and analyzed blind. Therefore, the results obtained in this study are more reliable.

As shown in Figure 34, the results of this study confirm our previous observations. Ascaris eggs were inactivated within 5 to 10 days at a dose of 1000 mg of lime per gram of sludge dry weight, but liming was ineffective at a dose of 100 mg per gram of sludge dry weight. Within the next year, experiments on the intermediate dosages between 100 and 1000 mg of lime per gram of solids (dry weight) will be conducted to obtain nomograms of the inactivation of Ascaris suum eggs by liming.

From the results of our two studies, lime stabilization of aerobically digested sludges appears to be feasible for Ascaris egg inactivation at dosages between 100 to 1000 mg of lime per gram solids. If the sludge is in an anaerobic state, lime dosages required for inactivation of Ascaris eggs will be an order of magnitude less than required for aerobic conditions.

In experiments conducted with caustic on aerobically stabilized sludges (3200 mg of sodium hydroxide per gram of solids), two important phenomena were observed: 1) the hydroxide concentration at a pH of 13 did not inactivate Ascaris eggs previously digested at 25°C; 2) all the Ascaris eggs were inactivated within ten days with a temperature increase of 10°C (to 35°C or mesophilic range). The first phenomenon illustrates that at 25°C in limed sludge, the inactivation of Ascaris was not due to the hydroxide but to the lime itself. The second indicates that when eggs are in sludge that is digested at higher temperatures and then held at pH 12 or above, parasite egg inactivation was enhanced. This may be due to the increased solubilization of toxic constituents (ammonia) in the sludge or to latent effects of the increased temperature. This solubilization can be a result of the increased hydrolysis constant of water which will in turn increase the acid disassociation constants for many constituents (57).

Ammonification--

As a result of recent studies by various Russian researchers (58,59) and inconclusive results from our first studies (11), the inactivation of Ascaris eggs by ammonification has been investigated. In our previous study (11) on aerobically digested sludges, the number of viable Ascaris eggs was reduced by 95% within 5 days, even in the control where no ammonia was added. In anaerobically digested sludges, no inactivation of eggs was observed at any dosage of ammonia up to 5000 milligrams of ammonia sulfate per gram of sludge suspended solids. In our first studies, there was either no reduction of viable Ascaris or Toxocara eggs in any of the sodium hydroxide and ammonia applications to anaerobically digested sludge under mesophilic conditions or no reduction as great as the control for Ascaris eggs in limed aerobically digested sludges at both 28°C and 35°C. This may be due to the fact that the free ammonia concentrations were not near 5% concentrations reported to be necessary to inactivate Ascaris eggs in anaerobic sludges by Russian researchers (58,59). As a result of these studies, the proper dosages of ammonia and a base for addition to aerobically digested sludges were restudied so that the above phenomena can be better understood.

In our previous study with 25°C aerobically digested sludge, inactivation of Ascaris eggs was noted at dosages of greater than 500 mg ammonium sulfate as ammonia per gram of sludge suspended solids in a caustic stabilized sludge. When the digestion temperature was increased to 35°C, the eggs appeared to be more sensitive with almost a complete inactivation occurring at dosages as low as 50 mg of ammonium sulfate within 5 days. Since similar inactivation was noted with the control, it appears that the influence of temperature was more predominant than the ammonium content in the inactivity of Ascaris.

When ammonia was added, inactivation of Ascaris eggs was observed in aerobically digested sludges at 25°C at ammonia concentrations equal to or greater than one-half a percent. The effectiveness of this inactivation was enhanced by increasing the digestion time and/or increasing the digester temperature before ammonification.

From this study, our previous study, and Russian studies, the following phenomena were noted: The ammonification dosages required for inactivation appeared to increase for greater contents of degradable carbon. Inactivation of Ascaris eggs required dosages of 5 percent of ammonia for anaerobically digested sludges, yet aerobically digested sludges needed only 1 percent of ammonia. As the detention time and temperature of the digestion process increased, the degradable organics were reduced and the inactivation of Ascaris eggs was enhanced. Since aerobic digestion under mesophilic conditions appeared to render the Ascaris eggs more susceptible to inactivation, liming, caustic stabilization, and ammonification appear to be more effective under these conditions. In addition, the application of ammonium sulfate was more effective under alkaline conditions than ammonification by ammonia alone. This effectiveness appeared to be enhanced by the high caustic applications (3200 milligrams of sodium hydroxide per gram at suspended solids) as the uncharged NH_3 form predominates at a pH of 9.3 or above.

At an estimated cost for liquid ammonia of $160.00 per ton, the cost for the ammonification by ammonia will be approximately one dollar and sixty cents per ton for a 1 percent sludge ($160/ton of sludge solids). Even though this initially appears to be expensive, it should be noted that municipal sludges are deficient in nitrogen. Before sludge can be utilized as a fertilizer, nitrogen would have to be added at a one to three percent level for proper nutrient requirements so this cost for inactivation would be required anyway. Therefore, this ammonia addition would serve a dual purpose.

Ultrasonication--

The results of our first study show that Ascaris eggs did not appear to be affected with low intensity ultrasonic (< 100 watts). Toxocara eggs, however, appeared to be significantly affected at 49 kHz and 26 watts after a 9-minute exposure and at 64 kHz and 74 watts after a 6-minute exposure. Thus, parasite egg inactivation by ultrasonication was a function of the type of parasite, ultrasonic frequency, minimum intensity and time of exposure. An optimum intensity is required for the destruction of Toxocara eggs with the effectiveness of treatment dropping as the frequency decreases below 30 kHz and increases above 64 kHz. Again, the effect of ultrasonics on Ascaris eggs was negligible at all values of ultrasonic frequencies and intensities attempted. With an increase in intensity, the destruction of Ascaris eggs is possible, but this hypothesis was not investigated in this study.

With a 600 watt and 33 kHz ultrasonic system, the inactivation of Ascaris was examined at different exposures in a flow-through system. Approximately 50 percent of the Ascaris was inactivated in five minutes, yet only 90 percent were inactivated over a 60-minute exposure. This data indicates that ultrasonics seem infeasible to inactivate Ascaris under field conditions. A recent Russian study (60) noted the need for 50 watts per milliter of sewage to inactivate Ascaris after exposure of 10 minutes. Our results appear to require even less power but still were inordinately high to be economical.

The application of ultrasound for inactivation of parasites in sludge and water seems very feasible for most parasites except Ascaris. For example, Toxocara, as compared to the intensity needed to inactivate Ascaris (600 watts), required one magnitude less intensity (60 watts) and exposure for complete destruction. Therefore, the efficacy of ultrasound appears to be parasite and sludge dependent, and should be investigated carefully for such parasites as Giardia, Toxocara, etc., in water treatment situations.

Irradiation with Cobalt 60—

The objectives of this study were to determine the effective dosage of Co^{60} irradiation for inactivating Ascaris eggs and to resolve the question of whether the radiation sensitivity of Ascaris eggs is altered by the removal of the outer layer of the egg shell.

In an earlier study, Melmed and Comninos (31) found that when 100 Krad from a Cobalt 60 source was applied to sludge containing Ascaris eggs, the number of eggs that were able to develop to the infective stage was reduced by 99%. However, they were unable to achieve complete inactivation of these eggs even at dosages of 500 Krads. In another study, Alexandre et al. (30), using gamma irradiation from a Cobalt 60 source, found that dosages of 400, 800, 1200 and 1800 Krads had no effect on Parascaris equorum eggs (= Ascaris megacephala) which still had their outer coat, while all four dosages killed these eggs when the outer layer of the shell was removed. Also, other workers achieved a 99.9% inactivation of Ascaris suum eggs by exposing them to 150 Krad of irradiation from Co^{60}; however, the eggs used in these experiments were from the uteri of worms and had been treated to remove the outer layer of the egg shell (61).

In the present study, three types of Ascaris suum eggs were used to determine if any differences in their sensitivity to irradiation could be detected; 1) intact eggs from the feces of naturally infected pigs, 2) eggs from the feces of naturally infected pigs that had the outer layer of their shells removed by exposure to 1% sodium hypochlorite, and 3) eggs from the uteri of worms that had the outer layer of their shell removed by the above method. Our results seem to clearly indicate that the three types of eggs do not differ in their sensitivity to gamma radiation and that dosages of 200 Krad or more will completely inactivate A. suum eggs in liquid sludges.

Since there are conflicting reports on the sensitivity to irradiation of Ascaris eggs in different stages of embryonation (37), the effective dosages of irradiation required to inactivate Ascaris eggs in more advanced stages of embryonation than the eggs used in the present study remain to be determined.

Several factors have been reported to affect the sensitivity of helminth eggs to irradiation. Increasing the temperature during exposure to radiation has been reported to increase the sensitivity of the eggs (31) and chemicals, such as calcium chloride, have been reported to be effective radiosensitizers and allow a reduction in a dosage required for inactivation (62). It would seem that additional studies are needed to determine whether there would be any advantages in combining irradiation with the use of various chemicals or with increased temperature.

Although it appears that gamma radiation from a Co^{60} (or Cesium-137) source has been the most frequently used method of inactivating pathogens in sludges and other material, other sources, i.e., x-rays and energized electrons, are equally effective when equivalent rads are used (63,64). An evaluation of the advantages and disadvantages of each type of radiation for disinfecting sludge is beyond the scope of this discussion.

SECTION 6

PART II. DEVELOPMENT OF A STANDARD METHOD FOR THE PARISITOLOGICAL EXAMINATION OF SLUDGE

DEVELOPMENT OF A STANDARD METHOD FOR THE PARASITOLOGICAL EXAMINATION OF WASTEWATER SLUDGES

The purpose of this part of the project was to develop a standard method for the parasitologic examination of wastewater sludges that could be used by technicians in wastewater laboratories and others for the monitoring of levels of parasites in sludges. The experimental studies were mainly carried out by Christian Ockenhouse as his thesis research for the Master of Science degree (65). A summary of the thesis research and subsequent studies is presented here.

Prior to initiating this study the following criteria were established to serve as guidelines for the development of a standard parasitologic method:

1. The technique should be able to process a relatively large sample of primary, stabilized or dewatered sludge so that low levels of parasites can be detected.

2. The techniques should not alter the morphology or the viability of parasite eggs or cysts so that accurate identification can be made and viability be determined.

3. The technique should be efficient (precise and accurate) and permit quantitation of the parasites.

4. The technique should be relatively simple and inexpensive, using materials and equipment normally found in wastewater laboratories.

With these criteria in mind the parasitologic techniques used by other workers in previous studies were reviewed and those that conformed to the above criteria were selected for further study.

The test organism in these studies, Ascaris suum eggs from the feces of naturally infected pigs, and Toxocara canis eggs from the feces of dogs, were prepared by the procedure described previously (11).

The procedures used in the parasitologic examination of sludge are divided into the general categories of pretreatment, concentration and microscopic examination for the purpose of discussion.

Pretreatment Procedures

It was found that the type of pretreatment required for a sample varied according to whether the type of sludge being examined was raw, primary (aerobic or anaerobic), or dewatered (drying bed, vacuum filtered or centrifuged). However, it was found that it is necessary to homogenize all samples of sludge, regardless of the type. To homogenize raw, primary or digested sludge, the samples are placed in a detergent and mixed with a magnetic stirrer. Previous workers had demonstrated that anionic detergents were better for this purpose than other types (66,67). It is thought that anionic detergents aid in releasing parasite eggs and cysts from sludge particles as well as in homogenizing the sludge particles. Several anionic detergents were found to be equally effective when a $ZnSO_4$ solution was used in a subsequent flotation procedure (Figure 43); however, in work carried out subsequent to Ockenhouse's thesis research, it was found that 0.1% Tween 80 was less effective than 1% "7X" when a $MgSO_4$ solution was subsequently used in the flotation step. It was also found that for mixing the sample in detergent, five minutes of mixing on a magnetic stirrer was usually sufficient to achieve homogenization of the sample (Figure 44).

In the case of dewatered sludges, it was found that samples needed to be mixed initially in a blender to break up the larger clumps. This blending must be done in water since excessive foam is produced if a detergent is used, and foam interferes with subsequent steps. Following the initial blending of dewatered sludge samples, the detergent solution is added and the sample is then mixed on a stirrer.

Some workers have used oxidants such as sodium hypochlorite to hydrolyze organic material and to release parasites from other particles in sludge (67). In our earlier study (11), we tested sodium hypochlorite and other oxidants such as perchloric acid and hydrogen peroxide and found disadvantages with each one. If sodium hypochlorite is used in sufficient strength to be effective, it removes the outer shell of many of the helminth eggs. Since the identification of eggs of some helminths, e.g., Ascaris and Toxocara, is based in part on the features of the outer layer of the shell, the use of sodium hypochlorite is not recommended.

An important step in the pretreatment procedure is allowing the homogenized sludge sample to settle for about one hour and then to decant the supernatant fluid. Many fine particles remain suspended in the supernatant fluid and when this is decanted they are removed from the sample. This effectively reduces the amount of material that is subsequently concentrated by flotation.

Another step that is useful in processing raw, primary and dewatered sludges is passing the homogenized sample through a series of graded sieves (10, 20. 50, 100 and 150 mesh). Since the openings in the smallest mesh (150 mesh) are about 106 um, particles larger than 106 um are retained on sieve while parasite eggs and cysts and other small particles pass through the sieve. It was found that this step could be eliminated in processing digested sludges since they contain relatively few large particles. With

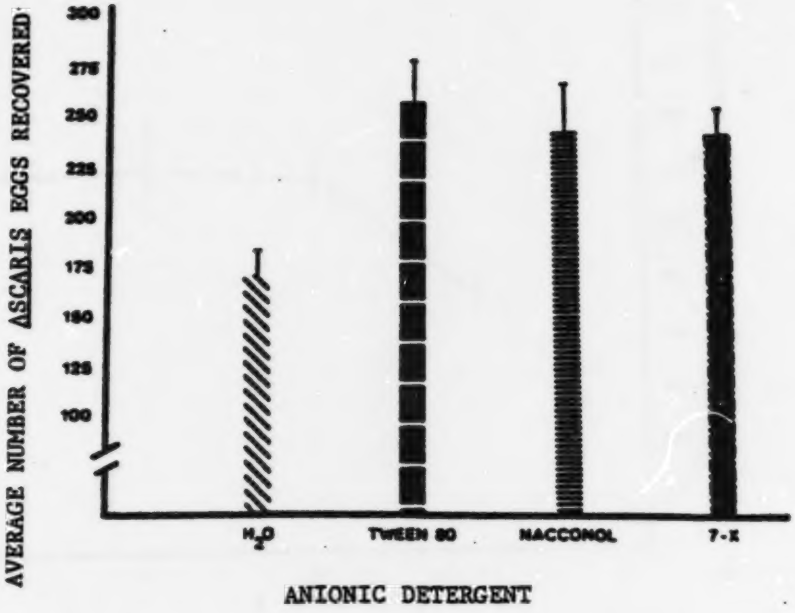


FIGURE 43. The influence of anionic detergents on the number average of *Ascaris* eggs recovered from field-collected drying bed sludge samples (65). (Initially, the sludge samples were blended twice in water and allowed to settle for 1 hour. The anionic detergents were added to the sludge sediment after the supernatant had been decanted and discarded. Each sample was stirred on a magnetic stirrer for 5 minutes. Then the sediment was concentrated using a flotation technique ($ZnSO_4$, sp. gr. 1.200) which was followed by a sedimentation technique (alcohol-acid-ether).)

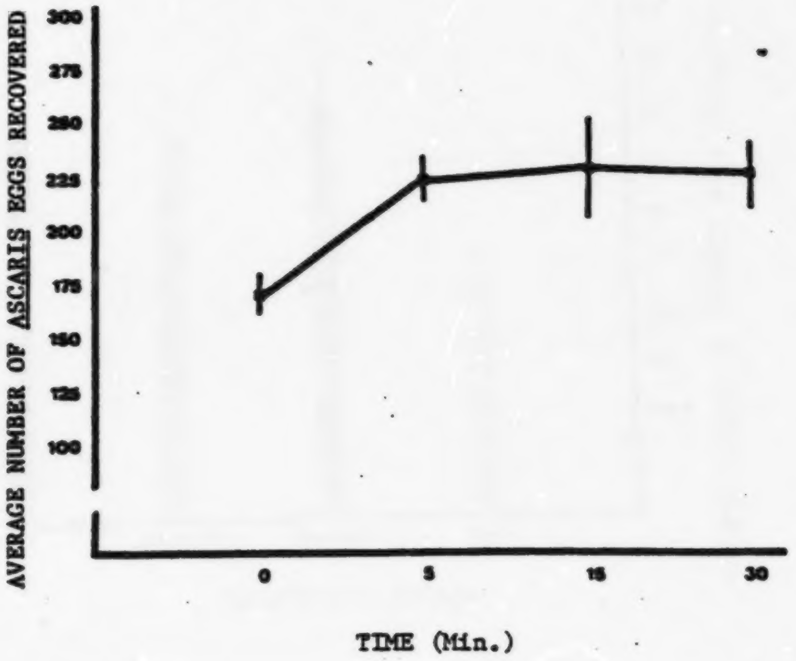


Figure 44. The average number of *Ascaris* eggs recovered from field-collected drying bed sludge samples, stirred for various periods of time in an anionic detergent, 0.1% Tween 80 (65). (The samples were initially blended twice in water and allowed to settle for 1 hour. The detergent was added to the sludge sediment after the supernatant was decanted and discarded. After each sample was stirred on a magnetic stirrer for the time indicated, it was concentrated using a flotation technique ($ZnSO_4$, sp. gr. 1.200) which was followed by a sedimentation technique (alcohol-acid-ether).

TABLE 67. COMPARISON OF THE EFFICIENCY OF VARIOUS FLOTATION SOLUTIONS FOR THE RECOVERY OF *ASCARIS* EGGS FROM ANAEROBIC DIGESTED SLUDGES (65)[1]

	TOTAL EGGS RECOVERED FLOTATION SOLUTION				
Determination	$MgSO_4$ Technical Grade	$ZnSO_4$ Technical Grade	Sheather's Solution[2]	NaCl	$ZnSO_4$ 5% KI
1	98	88	79	62	65
2	81	88	87	74	72
3	93	84	97	90	59
4	90	86	93	77	64
5	94	80	82	73	66
6	88	91	89	80	68
Average ± S.D.	90.7 ± 5.8	86.2 ± 3.8	87.8 ± 6.7	76.0 ± 9.2	65.7 ± 4.3
Mean % Recovery	64.7%	61.5%	62.7%	54.3%	46.9%

---

[1] 140 eggs added/75 ml sample; Specific gravity = 1.200 for all flotation solutions except for $ZnSO_4$ + 5% KI, sp. gr. 1.300.

[2] Sheather's solution consists of 500 grams sucrose + 320 ml water + 6.5 gm phenol.

TABLE 68. EFFECT OF SPECIFIC GRAVITY OF $ZnSO_4$ AND $MgSO_4$ SOLUTIONS ON THE RECOVERY OF TOXOCARA EGGS FROM ANAEROBIC DIGESTED SLUDGE (65)[1]

	MEAN NO. OF EGGS RECOVERED + S.D. (% Recovery)[2]	
Specific Gravity	$ZnSO_4$ Technical Grade Flotation Scale	$MgSO_4$ Epsom Salt Flotation Scale
1.180	16.8 ± 2.3 (56%)	15.8 ± 3.4 (53%)
1.200	19.0 ± 2.2 (63%)	20.0 ± 3.8 (67%)
1.250	19.6 ± 2.9 (65%)	18.0 ± 2.6 (60%)

[1] 30 *Toxocara* eggs added per 75 ml sample.

[2] 5 Determinations performed for each solution tested.

digested sludges the material recovered from the flotation step is passed through a 150 mesh sieve before it is processed further.

Concentration Procedures

In reviewing the literature it was found that, primarily, two types of concentration procedures have been employed for the recovery of parasites from sludges. One type uses flotation to separate parasites from denser particles, and the other uses sedimentation to separate parasites from lighter particles. At least one worker has used a combination of the two types with an initial sedimentation procedure followed by a flotation procedure (Lindquist, Revised Method; personal communication from Mr. Jeffery Bier, Div. Microbiology, FDA, Washington, D.C.).

In preliminary studies, it was found that most sedimentation procedures were not useful when used alone or as the initial method of concentration because of the large amount of small, dense particles found in sludge sediment along with the parasites. The amount of sediment resulting from these sedimentation procedures is relatively large, which makes it difficult to find and identify parasites in the sediment. For this reason efforts were primarily directed towards testing and evaluating flotation procedures used by other workers. The efficacy of several flotation solutions were evaluated, i.e., solutions of $ZnSO_4$, $MgSO_4$, NaCl, $ZnSO_4$ within 5% KI, and sucrose (Sheather's solution). It was found that MgSO4, ZnSO4 and sucrose solutions at 1.200 specific gravity were equally efficient but that NaCl at 1.200 sp. gr. and $ZnSO_4$ with 5% KI at 1.300 sp. gr. were less efficient (Table 67). It was also found that $MgSO_4$ solutions at specific gravity of 1.200 and 1.250 were more effective in recovering eggs than solutions of these salts at 1.180 sp. gr. (Table 68). Since it has previously been shown that protozoan cysts and some helminth eggs may be adversely affected by solutions with higher osmotic pressures, solutions with a specific gravity of 1.200 were chosen over those with higher specific gravities. $ZnSO_4$ and $MgSO_4$ solutions were chosen over sucrose solutions because they are easier to prepare and handle. It was found that Epsom salt ($MgSO_4$ USP) is equally effective as Technical Grade $MgSO_4$. Since the cost of Epsom salt is usually much less (75%) than that of Technical Grade $MgSO_4$, especially if purchased through a pharmacy, a flotation solution made from Epsom salt may be preferred.

The efficiency of the different methods used for recovering parasites that float to the surface of flotation solutions was also studied. While some investigators have used membrane filters to collect this material, we found this method to be impractical. It is very difficult to pass the flotation solution through these filters due to the rapid blockage of the pores and it was also difficult to recover parasites from the surface of these filters. In the procedure selected, the surface film and upper portion of the solution in the centrifuge tube are decanted and then water, three to four parts, is added to lower the specific gravity of the solution below that of the parasites. This mixture is then centrifuged and the sediment containing the parasites is recovered.

Because the amount of sediment recovered by the above procedures from most sludge samples is relatively large, it was concluded that further

TABLE 69. COMPARISON OF THE EFFICIENCY OF VARIOUS SEDIMENTATION PROCEDURES FOLLOWING A $ZnSO_4$ FLOTATION PROCEDURE ON THE RECOVERY OF ASCARIS AND TOXOCARA EGGS FROM SLUDGE SEDIMENT (65)[1]

Sedimentation Procedure	MEAN NO. OF EGGS RECOVERED ± S.D. (% Recovery)[2]	
	ASCARIS	TOXOCARA
Acid-Ether 0.27% H_2SO_4 + 35% Ethanol	52.25 ± 2.5 (87%)	51.75 ± 4.3 (86%)
Acid-Ether 0.27% CH_3COOH + 35% Ethanol	52.75 ± 1.3 (88%)	51.50 ± 3.7 (86%)
Acid-Ether 0.27% HNO_3 + 35% Ethanol	52.75 ± 4.6 (88%)	53.75 ± 2.4 (90%)
Sodium Sulfate Acid-Triton-Ether	40.00 ± 5.4 (67%)	51.50 ± 3.4 (86%)
Ethyl Acetate-Formalin	34.00 ± 6.5 (57%)	44.00 ± 5.0 (73%)
Ethyl Acetate - 0.27% H_2SO_4 + 35% Ethanol	9.50 ± 6.8 (16%)	6.75 ± 4.3 (11%)

---

[1] 60 Ascaris and 60 Toxocara eggs added per sample. Eggs were added to sediment immediately after the flotation ($ZnSO_4$) procedure.

[2] Based on 4 trials.

concentration of the parasites would be desirable in order to reduce as much as possible the time required for microscopic examination of the sediment. It was found that an ether sedimentation procedure would remove some of the particles in the sediment and thus further concentrate the parasites. Several modifications of the acid-ether sedimentation technique were evaluated and it was found that dilute solutions of H_2SO_4, HNO_3, and acetic acid in 35% ethanol were very effective solutions for use in this type procedure (Table 69). Alcohol was used in the solution to reduce specific gravity and surface tension. The action of the acid is not entirely known, but it is thought to affect the charges on the surface of parasites and sludge particles. In addition, the acid dissolves flocculent material that appears in some samples after the flotation step.

It was found that none of the steps used in pretreatment procedures steps or in the concentration procedures adversely affected the viability of helminth eggs. This method was used to recover Ascaris and Toxocara eggs from control samples in the experimental studies on disinfection techniques and the eggs showed no decrease in viability as determined by embryonation in cultures.

Microscopic Procedures

It was determined that a compound microscope must be used to detect eggs and cysts in sediments recovered from sludge samples. For optimum results, a suspension of the sediment produced by the concentration procedures should be placed on a glass slidge and covered with a coverglass of an appropriate size (more than one preparation may be necessary if the amount of sediment is large). The preparation is then examined by systematically traversing back and forth across the coverglass until all fields have been seen. Examination at 100X magnification is required to detect all eggs and cysts and identification must occasionally be made at higher power (X400).

The examination of sediment in a plastic or glass dish using a dissecting microscope or an inverted compound microscope was found to be unsatisfactory. It is difficult to detect all parasites in preparations in a dish and it is also difficult to use the higher power of the microscope in order to confirm the identity.

Sample Size

Preliminary tests indicated that the maximum amount of raw or digested sludge (5 to 10% solids) that can conveniently be examined at one time by the procedures selected was about 100 ml. With larger sample volumes, lower recoveries are observed, possibly due to solids interference. For dewatered sludge the maximum sample size was about 30 g (wet weight). Tests were conducted to determine whether the sample size affects the sensitivity and efficiency of the parasitologic method. It was found that the use of 100 ml of digested sludge was more sensitive ($p < 0.1$) in recovering Ascaris and Toxocara eggs than the use of a 75 ml sample (Figure 46). Also, the use of a 30 g sample of dewatered sludge was more sensitive in recovering Ascaris

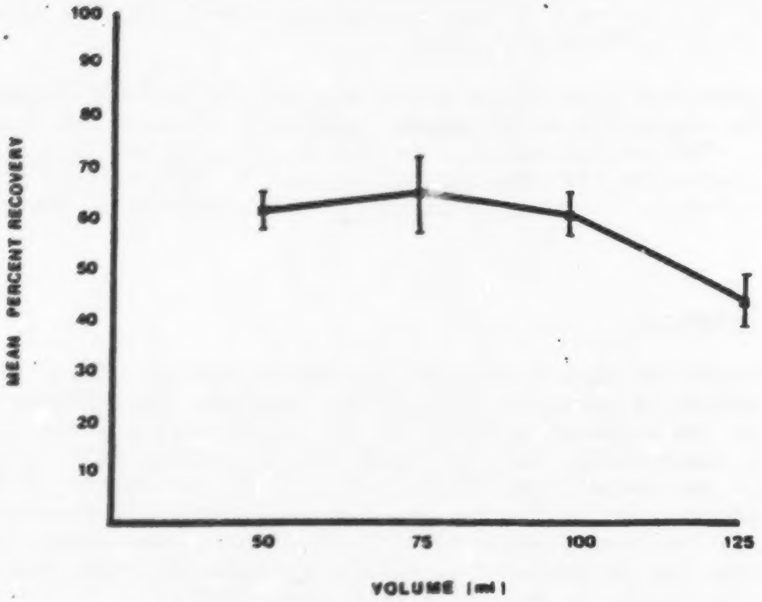


FIGURE 45. Effects of initial volume of digested sludge sample on the mean percent recovery of *Ascaris* eggs from anaerobic digested sludges (65). (Samples were processed using a flotation technique ($MgSO_4$, sp. gr. 1.200) which was followed by a sedimentation technique (alcohol-acid-ether). Data reported as mean percent recovery based on 5 trials.)

eggs ($p < 0.05$) and Toxocara eggs ($p < 0.01$) than the use of a 20 g sample. In examining primary sludge, no difference was found between the two sample sizes (100 ml and 75 ml) in recovering the eggs of either Ascaris or Toxocara.

PARASITOLOGIC METHOD FOR MUNICIPAL WASTEWATER SLUDGES

1. General Discussion

The eggs and cysts of parasites that are found in wastewater sludges are relatively small, usually less than 100 um, and often occur in small numbers. The following procedures are relatively large samples of liquid sludges (100 ml) and dewatered sludges (30 g) so that low densities of parasites can be detected. The method involves the separation of eggs and cysts from heavier particles by a flotation procedure and then separating eggs and cysts from lighter particles by a sedimentation procedure. The resulting sediment is then examined microscopically for the parasite.

2. Apparatus and Materials

a. Centrifuge. IEC floor model, or similar centrifuge with horizontal rotor and shields for eight 50 ml tubes.

b. Centrifuge. General bench-top type with horizontal rotor and shields for 15 ml conical centrifuge tubes.

c. Magnetic Stirrer. Stirrer with one or more placed and with 5 cm (2 in.) stirring bars.

e. Heavy Duty Laboratory Stirrer. Waring Blender, or similar blender, with mixing cup of 1000 ml or more capacity.

f. Ultrasonic Cleaner. Ultrasonic cleaner with tank dimensions of approximately 12" x 6" x 6".

g. Compound Binocular Microscope. Microscope should have at least 10X and 40X objectives and 10X eyepieces.

h. Beakers. 1000 ml, tall form, Berselius Pyrex; and 1000 ml, low-form, Kimax.

i. Funnels. Powder filling, 150 mm, Nalgene.

j. Sieves. Market Grade, brass, 5 in. diameter. Sieves of 10, 20, 50. 100 and 150 mesh.

k. Hydrometer. Specific gravity range of 1.000 to 1.250.

l. Wash Bottles, Plastic. 500 and 1000 ml; and plastic, 750 ml, with trigger spray head.

m. Centrifuge Tubes. Conical polypropylene, 50 ml; and conical, Pyrex, 15 ml.

n. Pipettes. Pasteur disposable, 5-3/4 in.

o. Microscope Slides. Glass, 3 x 2 in.

p. Coverglass. 22 x 30, 24 x 40, and 24 x 50 mm.

q. Culture Dishes. Any of the following may be used, but no. 1 is less expensive.

1) Beakers 2.5 ml, flat bottom, polystyrene (diSPo^R Beaker, American S/P No. B2714-1) with polyethylene snap-on cap (diSPo^R Beaker Cap, American S/P No. B2716-10)

2) Tissue culture dish, clear polystyrene, 35 x 10 mm.

3) Multiwell tissue culture plate, polystyrene.

3. Reagents

a. Anionic Detergent Solution. 1% "7X": Dilute 10 ml "7X" (Linbro Chemical Co., Inc., New Haven, CT) to 1000 ml with water.

b. Flotation Solution. Dissolve $MgSO_4$-$7H_2O$ (USP or ACS) or $ZnSO_4$-$7H_2O$ in water and adjust to sp. gr. 1.200 with hydrometer. (Add 600 mg of $MgSO_4$-$7H_2O$ to 1000 ml distilled water, or 341 g of $ZnSO_4$-$7H_2O$ to 880 ml of distilled water. (Epsom salts, $MgSO_4$-$7H_2O$ USP, may be purchased cheaper through a pharmacy than through a laboratory supply company.)

c. Alcohol-Acid Solution. Dilute 2.7 ml of conc. H_2SO_4 to 1000 ml with 35% ethanol. Prepared 35% ethanol by diluting 350 ml of 95% ethanol to 950 ml with water.

d. Ether. Anhydrous.

e. Culture Fluid. 0.1N H_2SO_4: Dilute 2.7 ml of conc. H_2SO_4 to 1000 ml with water.

4. Procedure

a. Samples of Raw, Primary or Imhoff Sludges:

1) Place 100 ml of a thoroughly mixed sludge sample into blender mixing cup, add 200 ml of water, and mix on blender for 30 seconds.

2) Pour blended sample into 1000 ml beaker, tall form, and add 1% "7X" to 900 ml. (Rinse blender cup into beaker

with portion of 1% "7X".)

3) Let settle for 1 hour, then decant supernatant by pouring it off.

4) Add 250 ml of 1% "7X" to sediment, and mix for 5 minutes on magnetic stirrer.

5) Strain homogenized material through a series of graded sieves, 10, 20, 50, 100 and 150 mesh in sequence listed. Each sieve is placed on a funnel over a 1000 ml beaker and the sample washed through sieve with aid of stream or spray from a wash bottle containing 1% "7X". (Before sieves are used again, they should be placed in ultrasonic cleaner for 5 minutes and then washed thoroughly.)

6) After passing sample through all five sieves, let it settle in 1000 ml beaker for 1 hour.

7) Decant supernatant by pouring it off or by aspiration and discard it; mix the remaining sediment and distribute it equally to four 50 ml centrifuge tubes; bring volume in each tube to 50 ml by adding water.

8) Centrifuge the tubes for 5 minutes at 800 g; pour off supernatant and discard. (The packed sediment in each tube should not exceed 5 ml, if so, add water and distribute among additional tubes as required; repeat centrifugation and decant.)

9) Add about 10 ml of flotation solution to packed sediment in each tube and mix for 15 to 30 seconds on a vortex mixer. (Use care not to cause splashing of mixture from tube.)

10) Add flotation solution to each tube to bring volume to 50 ml; centrifuge for 5 minutes at 800 g.

11) When the centrifuge has come to a complete stop without breaking, remove tubes and pour the top 25 to 30 ml of supernatant from each tube into a 1000 ml beaker while rotating tube to allow all floating material to be poured off with supernatant. Discard sediment in tube.

12) Estimate volume of supernatant poured into beaker and add about 4 times as much water to beaker to dilute solution (specific gravity should be lowered to 1.050 or less); mix by stirring.

13. Distribute diluted solution to eight 50 ml centrifuge

tubes and centrifuge for 5 min. at 800 g; discard supernatant by pouring off. Repeat procedure of adding more solution to tubes, centrifuging and decanting. Repeat until entire volume has been processed in this way. Carefully rinse beaker into tubes using a stream of water from a squirt bottle before final centrifugation.

14) Transfer sediment from 50 ml tubes with a Pasteur pipette to one or more 15 ml conical centrifuge tubes; use stream of water from squirt bottle to completely rinse each 15 ml tube and transfer to the smaller tube. Fill 15 ml tube to near top, balance in centrifuge with another tube, and centrifuge for 3 min. at 800 g. If sediment exceeds 1.5 ml, dilute in water, mix, distribute to one or more tubes as required and centrifuge as above.

15) Pour off supernatant and add 2 ml of alcohol-acid solution to packed sediment; mix thoroughly on a vortex mixer and add 7 ml of alcohol-acid solution.

Steps 16 - 18 should be carried out under a hood.

16) Add 3 ml of ether, place stopper in tube and shake vigorously for 30 seconds.

17) Centrifuge at 800 g for 3 minutes.

18) After removing the stopper, use an applicator stick to loosen the layer of material at the interface of the ether and alcohol-acid solutions by ringing the inner circumference of the tube; pour off the entire supernatant into a safety can by quickly inverting the tube. Touch tip of tube to a paper towel or tissue to remove excess fluid and to prevent it from draining back into the tube.

19) With a Pasteur pipette, mix sediment with fluid remaining in tube (it may be necessary to add a drop or two of water, depending on size of sediment) and transfer to glass microscope slide. Cover with a coverglass of an appropriate size (20 x 30 mm or 22 x 40 mm recommended). Fluid should not extend beyond edge of coverglass. Additional preparations may be necessary to examine all sediment.

20) Systematically examine each preparation under at least 100X magnification (10X objective and 10X eyepieces) of a compound binocular microscope and record the number of each parasite (egg, cysts, etc.) found.

For verifying the identification, examination under higher magnification may be necessary (40X objective). Slide is systematically examined by starting at one corner of coverglass, traversing across the preparation slowly, and when opposite side of coverglass is reached, the slide is moved so that the adjoining field is in view; the slide is then traversed again to the opposite side; this is repeated until entire preparation has been examined.

b. Samples of Aerobic and Anaerobic Digested Sludge

1) Place 100 ml of a thoroughly mixed sludge sample into a 1000 ml beaker, low form, and add 1% "7X" to about 400 ml. Stir for 5 minutes on a magnetic stirrer.

2) Add 1% "7X" to 900 ml and let settle for 1 hour.

3) Decant supernatant by pouring it off or by aspiration and discard it; mix the remaining sediment and distribute it equally to four 50 ml centrifuge tubes; bring volume in each tube to 50 ml by adding water.

4) Centrifuge for 5 minutes at 800 g; pour off supernatant and discard. (The packed sediment in each tube should not exceed 5 ml; if so, add water and distribute among additional centrifugation tubes and decant.)

5) Add about 10 ml of flotation solution to packed sediment in each tube and mix for 15 to 30 seconds on a vortex mixer. (Use care not to cause splashing of mixture from tube.)

6) Add flotation solution to each tube to bring volume to 50 ml; centrifuge for 5 minutes at 800 g.

7) Place 150 mesh sieve on funnel over 1000 ml beakers and when the centrifuge has come to a full stop, remove tubes and pour the top 25 to 30 ml of supernatant from each tube through sieve into beaker while rotating tube to allow all floating material to be poured off with supernatant. Rinse the sieve with water from a spray bottle through funnel. Discard sediment left in tubes.

8) Estimate volume of supernatant poured into beaker and add about 4 times as much water to beaker to dilute solution (specific gravity should be lowered to 1.050 or less); mix by stirring.

9) Distribute diluted solution to eight 50 ml centrifuge tubes and centrifuge for 5 minutes at 800 g; discard supernatant by pouring off. Repeat procedure by adding

more solution to tubes, centrifuging and decanting. Repeat until entire volume has been processed this way. Carefully rinse beaker into tubes using a stream of water from a squirt bottle before final centrifugation.

Proceed as in Steps 14 to 20 for 4a (Samples of Raw or Primary Sludge).

c. Samples of Dewatered and Composted Sludge

1) Place 30 gm of dewatered or composted sludge in a blender mixing cup, add 200 ml or water, and mix on a blender for 30 seconds at high speed.

2) Pour blended sample into 1000 ml beaker, tall form, and add 1% "7X" to 900 ml. (Rinse blender cup into beaker with portion of 1% "7X".)

3) Let settle for at least 3 hours, but preferably overnight. (If material remains floating on surface, occasionally stir upper levels of mixture to remove air bubbles. Allow to settle at least 1 hour without stirring.) Pour off and discard supernatant.

4) Add water to 300 ml, transfer to blender mixing cup and mix on blender to 30 seconds at high speed.

5) Pour blended sample into 1000 ml beaker, tall form, and add 1% "7X".

6) Let settle for 1 hour, then pour off supernatant and discard.

7) Add 250 ml of 1% "7X" and mix on a magnetic stirrer for 5 minutes.

Proceed as in Steps 5 to 20 for 4a (Samples of Raw or Primary Sludge).

d. Determination of Viability of Helminth Eggs by Culturing

The viability of certain helminth eggs recovered from sludge samples (i.e., *Ascaris*, *Toxocara*, *Trichuris*) can best be determined by culturing. The sediment recovered from a sludge sample by one of the methods given in 4a-c can be placed in a culture before or after microscopic examination. If the sample is examined first, the material from each slidge preparation must thoroughly be washed from the slide into a tube or beaker as soon as possible after microscopic examination. When all sediment in the sample has been examined and then washed into a tube or beaker, the material is sedimented by centrifugation. The sediment recovered following the above procedure or from Step 18 of 4a-c is treated as follows:

1) Add 2-3 ml of culture fluid to sediment in tube, mix on vortex mixer, and bring volume to 15 ml with culture field.

2) Centrifuge for 3 minutes at 800 g and pour off supernatant.

3) Add a few drops of culture fluid to sediment, mix with clean pipette, and transfer to culture dish. Rinse tube and pipette with about 0.5 ml of culture fluid and add to dish. Add additional culture fluid to dish, if necessary, to bring depth of fluid to 3 to 4 mm.

4) Cover culture dishes and store in darkness or in subdued light at 22-28 C. Agitate dishes every few days to mix sediment and aerate fluid.

5) After a minimum of 21 days, transfer the cultured sample to a 15 ml conical centrifuge tube.

6) Centrifuge for 3 minutes at 800 g and pour off supernatant.

7) Transfer sediment to one or more slides and examine as in Steps 19 and 20 of 4a above.

8) A viable egg of Ascaris, Toxocara, Trichuris or similar helminth will contain a coiled, living larva within the egg shell. If an egg is dead (nonviable) there will be only a mass of coarsely granular material within the egg shell.

5. Calculations

The number of eggs of each type of helminth parasite is expressed as number per kilogram of sample, dry weight. The following forumula is used for the calculation:

$$\text{No. eggs/kg dry weight of sample} = \left(\frac{\text{No. eggs in sample}}{\text{g dry weight of sample}}\right)\left(\frac{1000\text{ g}}{1\text{ kg}}\right)$$

The formula for calculating the gram dry weight of a sample is shown below:

For liquid sludge;

$$\text{g dry weight} = \left(\frac{\text{Mg of Total Solids}}{\ell}\right)\left(\begin{matrix}\text{Sample Size}\\ \text{in Liters}\end{matrix}\right)\left(\frac{10^{-3}}{\text{mg.}}\right)$$

For dewatered, drying bed, and composted sludge;

$$\text{g dry weight} = \left(\frac{\text{Percent Solids}}{100}\right)\left(\begin{matrix}\text{Sample Weight}\\ \text{in g}\end{matrix}\right)$$

REFERENCES

1. Hays, B.D. Is There a Potential for Parasitic Disease Transmission from Land Application of Sewage Effluents and Sludges? J. Environ. Hlth., 39:424-426, 1977.

2. Akin, E.W., W. Jakubowski, J.B. Lucas, and H.R. Pahren. Health Hazards Associated with Wastewater Effluents and Sludge: Microbiological Considerations. In: Proceedings of the Conference on Risk Assessment and Health Effects of Land Application of Municipal Wastewater and Sludges. B.P. Sagik and C.A. Sorber, eds., Univ. Texas-San Antonio and Nat. Sci. Found., 1978. pp. 9-26.

3. Clark, C.S., E.J. Cleary, G.M. Schiff, C.C. Linnemann, J.P. Phair, and T.M. Briggs. Disease Risks of Occupational Exposure to Sewage. J. Environ. Eng. Div. ASCE, 102:375-388, 1976.

4. Wiley, B.B., and S.C. Westerberg. Survival of Human Pathogens in Composted Sewage. Appl. Microbiol., 18:944-1001, 1969.

5. Sagik, B.P., and C.A. Sorber, eds., 1978. Proceedings of the Conference on Risk Assessment and Health Effects of Land Application of Municipal Wastewater and Sludges. Dec. 12-14, 1977. Univ. Texas-San Antonio and Nat. Sci. Found., 1978. 329 pp.

6. Connery, J., E. Epstein, F. Guymont, S. Marcus, F. Passman, J. Post, and W. Taffel. Workshop on the Health and Legal Implications of Sewage Sludge Composting. Dec. 18-20, 1978. Energy Resources Co., Inc., Cambridge, Massachusetts, 1979.

7. Bitton, G., B.L. Damron, G.T. Edds and J.M. Davidson, eds. Sludge-Health Risks of Land Application. Ann Arbor Science Publishers, Inc., Ann Arbor, Michigan, 1980. 367 pp.

8. Fox, J.C., P.R. Fitzgerald and C. Lue-Hing. Sewage Organisms: A Color Atlas, The Metropolitan Sanitary District of Greater Chicago, Chicago, Illinois, 1981. 116 pp.

9. Theis, J.H., V. Volton and D.R. Storm. Helminth Ova in Soil and Sludge from Twelve U.S. Urban Areas. J. Water Pollut. Contr. Fed., 50:2485-2493, 1978.

10. Jackson, G.L., J.W. Bier, and R.A. Rude. Recycling of Refuse into the Food Chain: The Parasite Problem. In: Proceedings of the Conference on Risk Assessment and Health Effects of Land Application of Municipal Wastewater and Sludges. B.P. Sagik and C.A. Sorber, eds., Univ. of Texas-San Antonio and Nat. Sci. Found., 1978. pp. 116-125.

11. Reimers, R.S., M.D. Little, A.J. Englande, D.B. Leftwich, D.D. Bowman and R.F. Wilkinson. Parasites in Southern Sludges and Disinfection by Standard Sludge Treatment. Final Project Report to Municipal Environmental Research Laboratory, U.S. EPA. Cincinnati, Ohio, 1981. 191 pp. (NTIS No. PB 82-102 344)

12. Little, M.D. Agents of Health Significance: Parasites. In: Sludge Health Risks of Land Application, G. Bitton *et al.*, eds., Ann Arbor Science Publishers, Inc., Ann Arbor, Michigan, 1980. pp. 47-58.

13. Krasnonos, L.I. Many-Year Viability of Ascarid Eggs (*Ascaris lumbricoides*) in Soil of Samarkand. Med. Parasitol., 47:103-106, 1978. Abstract in: Trop. Dis. Bull., 75(10):991-992, 1978.

14. Müller, G. Untersuchunger Über die Lebensdauer von Askarideneirer in Gartenerde. Zbl. Bakt. Abt. I Orig., 159:377-379, 1953.

15. Feachem, R. G., D.J. Bradley, H. Garelick, and D.D. Mara. Appropriate Technology for Water Supply and Sanitation. Health Aspects of Excreta and Sullage Management - A State-of-the-Art Review. The World Bank, Washington, D.C., 1980. 318 pp.

16. Frenkel, J.K., A. Ring, and M. Chinchilla. Soil Survival of *Toxoplasma* Occysts in Kansas and Costa Rica, Am. J. Trop. Med. Hyg., 24:439-443, 1975.

17. Cram, E.B. The Effect of Various Treatment Processes on the Survival of Helminth Ova and Protozoan Cysts in Sewage. Sewage Works J., 15:1119-1138, 1943.

18. Wang, W.-L.L., and S.G. Dunlop. Animal Parasites in Sewage and Irrigation Water. Sewage Indust. Wastes, 26:1020-1032, 1954.

19. Greenburg, A.E., and B.G. Dean. The Beef Tapeworm, Measley Beef, and Sewage - A Review. Sewage Indust. Wastes, 30:262-269, 1958.

20. Vassilkova, Z.G. Sur la Deshelminthisation des Eaux d'Egout Epurees par Methodes Intenses. Med. Parasitol. Parasit. Dis., 5(5):657-673, 1936. Abstract in: Helminthol. Bastr., 5:139-140, 1936.

21. Silverman, P.H., and R.B. Griffiths, A Review of Methods of Sewage Disposal in Great Britain, with Special Reference to the Epizootiology of *Cysticercus bovis*. Ann. Trop. Med. Parasitol., 49:436-450, 1955.

22. Newton, W.L., H.J. Bennett, and W.B. Figgat. Observations on the Effects of Various Sewage Treatment Processes Upon the Eggs of Taenia saginata. Am. J. Hyg., 49:166-175, 1949.

23. Liebmann, H. Parasites in Sewage and the Possibilities of their Extinction. In: Proceedings of the Second International Conference. Advances in Water Pollution Research. Tokyo, 1964. Vol. 2, J.K. Baars, ed., Pergamon Press, 1965. pp. 269-279.

24. Panicker, P.V.R.C., and K.P. Krishnamoorthi. Parasite Eggs and Cyst Reduction in Oxidation Ditches and Aerated Lagoons. J. Water Pollut. Contr. Fed., 53(8):1413-1419, 1981.

25. Schmidt, C.J., I. Kugelman and E.V. Clements III. Municipal Waste-Water Reuse in the U.S. J. Water Pollut. Contr. Fed., 47(9):2229-2245, 1975.

26. Braun, R. Problems of Sludge Disposal. In: Proceedings of the Second International Conference. Advances in Water Pollution Research, Tokyo, 1964. Vol. 2, J.K. Baars, ed., Pergamon Press, 1965. pp. 217-230.

27. Passman, F.J. Biology of Sludge Pathogens. In: Workshop on the Health and Legal Implications of Sewage Sludge Composting. Energy Resources Co., Inc., Cambridge, Massachusetts, 1978. pp. 35-51.

28. Mercado-Burgos, N., R.C. Hoehn, and R.B. Holliman. Effect of Halogens and Ozone on Schistosoma Ova. J. Water Pollut. Contr. Fed., 47:2411-2419, 1975.

29. Burleson, G.R., and M. Pollard. Inactivation of Microorganisms by Ozonation or Ozonation and Sonication. (Progress Report to Telecommunications Industries, Inc.) Lobund Laboratory, Notre Dame, Indiana, 1976. 20 pp.

30. Alexandre, D., P. Gevaudan, J. Charrel, M.N. Mallet, A. Blanchard, and M.J. Gevaudan. La Desinfection des Boues Residuaires Urbaines. T.S.M.L. Eau, 70th yr., No. 12, 1975. pp. 547-555.

31. Melmed, L.N., and D.K. Comninos. Disinfection of Sewage Sludge with Gamma Radiation. Water So. Afr., 5:153-159, 1979.

32. Reyes, W.L., C.W. Kruse, and M. St. C. Batson. The Effect of Aerobic and Anaerobic Digestion on Eggs of Ascaris lumbricoides var. suum in Night Soil. Am. J. Trop. Med. Hyg., 12:46-55, 1963.

33. Arther, R.G. Viability and Infectivity of Parasitic Nematode Ova in an Anaerobically Digested Sewage Sludge. Doctoral Dissertation, University of Illinois at Urbana-Champaign, 1979. 93 pp. (University Microfilms Intl., Ann Arbor, Michigan, No. 7915313).

34. Monthly Report, October 1981, Municipal Environmental Research Laboratory, U.S. EPA, Cincinnati, Ohio.

35. Monthly Report, January, 1982, Municipal Environmental Research Laboratory, U.S. EPA, Cincinnati, Ohio.

36. Stern, G., and J.B. Farrell. Sludge Disinfection Techniques. In: Proceedings of National Conference on Composting of Municipal Residues and Sludges, Washington, D.C., Information Transfer, Inc., Rockville, Maryland, 1977. pp. 142-148.

37. Brandon, J.R. Parasites in Soil/Sludge System. In: 5th National Conference on Acceptable Sludge Disposal Techniques: Cost, Benefit, Risk, Health and Public Acceptance, Orlando, Florida. Information Transfer, Inc., Rockville, Maryland, 1978. pp. 130-133.

38. Ouelette, R.P., J.S. King, and P.N. Cheremisinoff. Electrotechnology Volume 1 - Wastewater Treatment and Separation Methods. Ann Arbor Science Publishers, Inc., Ann Arbor, Michigan, 1978. 609 pp.

39. Murry, E.J. An Ultrasound Future or a Sound Sleep. Part III. Uses in Variety. Chem. Technol., 5:376-381, 1975.

40. Sierra, G., and R.M. Beucher. Ultrasonic Synergistic Effects in Liquid-Phase Chemical Sterilization. Appl. Microbiol., 22:160-164, 1971.

41. Ordonez, J.A., and J. Burgos. Effect of Ultrasonic Waves on the Heat Resistance of Bacillus Spores. Appl. Environ. Microbiol., 32:183-184, 1976.

42. Dakubu, S. Cell Inactivation by Ultrasound. Biotechnol. Bioeng., 18:465-471, 1976.

43. Stumpf, P.K., D.E. Green, and F.W. Smith. Ultrasonic Disintegration as a Method of Extracting Bacterial Enzymes. J. Bacteriol., 51(4):487-493, 1946.

44. Schmitt, F.O., and B. Uhlemeyer. The Mechanism of Lethal Effects of Ultrasonic Radiation, Proc. Soc. Exptl. Biol. Med., 27(7):626-628, 1930.

45. Ballanger, M.E., W.J. Brasher, and C.C. Maupin. Water Contamination and the Ultrasonic Scaler, Va. Dental J., 53(3):10-14, 1976.

46. Coakley, W.T., A.J. Bater, and D. Lloyd. Disruption of Micro-organisms, Adv. Microbial Physiol. A.H. Rose and D.W. Tempest, eds., vol. 16, Academic Press, New York, 1977. pp. 279-341.

47. Wang, L.K., M.H. Wang, and G.G. Peery. General Theories of Chemical Disinfection and Sterilization of Sludge - Part 2, Water Sewage Words, 125(8):58-63, 1978.

48. Morishita, K. Studies on Epidemiological Aspects of Ascariasis in Japan and Basic Knowledge Concerning its Control. In: Progress of Medical Parasitology in Japan, K. Morishita, Y. Komiya, and H. Matsubayashi, eds., Vol. 4, Meguro Parasitology Museum, Tokyo, Japan, 1972. pp. 1-153.

49. Greenberg, A.E., J.J. Conners, and D. Jenkens. Standard Methods for the Examination of Water and Wastewater. 15th Ed. American Public Health Association, Washington, D.C., 1980. 1134 pp.

50. Beer, R.J.S. Experimental Infection of Man with Pig Whipworm. Med. J., 2:44, 1971.

51. Harper, K.L., M.D. Garfield, and F.A. Ehrenford. Human Infection with Canine Whipworm. J. Indiana St. Med. Assn., 57:24-27, 1964.

52. David, E.D. and W.D. Lindquist. Determination of the Specific Gravity of Certain Helminth Eggs Using Sucrose Density Gradient Centrifugation. J. Parasitol., 68:916-919, 1982.

53. Glickman, L.T., P.M. Schantz, and R.H. Cypess. Canine and Human Toxocariasis: Review of Transmission, Pathogenesis and Clinical Disease. J. Am. Vet. Med. Assn., 175:1265-1269, 1979.

54. Carroll, T.E., D.L. Maase, J.M. Genco, and C.N. Ifeadi. Review of Landspreading of Liquid Municipal Sewage Sludge. Environmental Protection Technology Series, EPA-670/2-75-049, U.S. EPA, Cincinnati, Ohio, 1975. 96 pp.

55. Black, M.I., P.V. Scarpino, C.J. O'Donnell, K.B. Meyer, J.V. Jones, and E.S. Kaneshiro. Survival Rates of Parasite Eggs in Sludge During Aerobic and Anaerobic Digestion. Appl. Environ. Microbiol. 44:1138-1143, 1982.

56. Reyes, W.L., C.W. Kruse, and M. St. C Batson. The Effect of Aerobic and Anaerobic Digestion on Eggs of *Ascaris lumbriocoides* var. *suum* in Night Soil. Am. J. Trop. Med. Hyg., 12:46-55, 1963.

57. Stumm, W., and J.J. Morgan. 1981. Aquatic Chemistry: An Introduction Emphasizing Chemical Equalibria in Natural Waters. 2nd Ed. John Wiley & Sons, New York, 1981. 780 pp.

58. Chilikin, M.M. (Disinfection from Helminth Ova by Ammonium Hydroxide and Carbathion of the Mechanically Separated Solid Part of Sewage.) Voprosy Med. Gel'mintol. (Nauchnye Trudy), 1976. pp. 21-26. Abstract in: Helminthol. Abstr., Ser. A, 47(3):129, 1978.

59. Chefranova, Yu A., R.F. Davydova, and L.I. Organiv, 1976. (Helminthological Assessment of the Solid Part of Sewage Used as Fertilizer after Treatment with Ammonia.) Voprosy Med. Gel'mintol. (Nauchnye Trudy), 1976. pp. 61-70. Abstract in: Helminthol. Abstr., Ser. A, 47(3):129, 1978.

60. Sokhrokov, Kh. Kh. The Ovicidal Parameters of Ultrasound for Pig Nematode Ova. Veterinariya, Moscow, No. 1, 1979. pp. 56-57. Abstract in: Helminthol. Abstr., Ser. A, 46(6):277, 1979.

61. Brandon, J.R. Sandia's Sludge Irradiation Program. In: Proceedings of the Third National Conference on Sludge Management, Disposal and Utilization, Miami Beach, Florida. Information Transfer, Inc., Rockville, Maryland, 1977. pp. 135-137.

62. Kuz'mina, O.O. (Radiation Method of Disinfection of Farm Liquid Manure.) Byulleten' Vsesoyuznogo Institiuta Gel'mintologii im. K.I. Skrayabina, No. 29, 1981. 87 pp. Abstract in: Helminthol. Abstr., Ser. A, 51(11): 621, 1982.

63. Trump, J.G. Energized Electrons Tackle Municipal Sludge. Am. Scientist, 69:276-284, 1981.

64. Cherepanov, A.A. (The Use of a High-Energy Electron Accelerator for the Decontamination of Liquid Manure from Helminth Ova.) Byulleten' Vsesoyuznogo Instituta Gel'mintologii im. K.I. Skryabina, 25:67-69, 1980. Abstract in: Helminthol. Abstr., Ser. A., 51(9):476, 1982.

65. Ockenhouse, C.F. The Development of Techniques for the Recovery of Parasite Eggs from Sewage Sludges. Masters Thesis, Department of Parasitology, The Graduate School, Tulane University, New Orleans, Louisiana, 70112, 1980. 88pp.

66. Steer, A. G., J.H. Nell, and S.G. Wiechers. A Modification of the Allen and Ridley Technique for the Recovery of _Ascaris lumbricoides_ Ova From Municipal Compost. Water Res., 8:851-853, 1974.

67. Meyer, K.B., K.D. Miller, and E.S. Kaneshiro. Recovery of _Ascaris_ Eggs From Sludge. J. Parasitol., 64(2):380-383, 1978.

APPENDIX A. LETTER, ENCLOSURE AND FORM FOR FIELD STUDY

TULANE UNIVERSITY
School of Public Health and Tropical Medicine
NEW ORLEANS, LA. 70112 U.S.A.

Department of Tropical Medicine
1430 Tulane Avenue

A team composed of members of the Departments of Environmental Health and Tropical Medicine at the School of Public Health and Tropical Medicine of Tulane University has been awarded a grant by the Environmental Protection Agency to study the prevalence of the resistant stages of human and animal parasites in municipal sewage sludges in four northern states, i. e. Minnesota, New York, Ohio, and Washington. On completion of this study, we will compare the data collected from waste treatment plants in these states with data that we have collected over the past two years from waste treatment plants in five southern states. Our study is not concerned with plant efficiency or effluent BOD or COD levels, and our reports to the Environmental Protection Agency will designate each plant by number only. We plan to collect samples from each of the treatment plants selected for study three times during the next year at about four month intervals.

After examining the information contained in the supplied to us by Mr. of the Pollution Control Agency, we have selected your plant, based on its location, treatment process, and size, as one of the plants in that we would like to study. During an initial visit by myself and another team member, we would like to collect two, 1 liter samples (the actual sample size depends on the consistency of the sludge) from three different points along the treatment process.

I am writing to request your permission to collect these samples. Once again I would like to stress that we are not concerned with operational or effluent quality, but only with the numbers and types of parasites present and the effect that different treatment processes might have on these parasites. Would you please complete the enclosed sheet and return it in the stamped envelope. Besides asking for the phone number of the plant and the name of the person that we should contact at the plant, the form asks for the directions to the plant since our previous experience has shown that these plants are often difficult to find. Also, we would like to know the normal operational hours of the plant, since we are trying to visit about fifteen plants in a four-day period and will need to know the hours during which the full staff will be on duty so that we can plan our trips accordingly.

Thank you very much for your time and consideration, and please mail the enclosed sheet as soon as possible, since we would like to plan our first trip for the week of

Sincerely yours,

APPENDIX A. (Continued)

To:

Dept. of Tropical Medicine
1430 Tulane Avenue
New Orleans, LA 70112

Plant:

Telephone No. (__) ____________________

Person to Contact at Plant: ____________

____

Normal Hours of Full Staff Operations:

Monday - Friday ____________________

Directions to Plant: ____________________

____

APPENDIX A. (Continued)

Recent governmental regulations have required the improvement of the quality of waste water discharged from municipal sewage plants, and this in turn has led to the production of increased amounts of sewage sludge. The application of more stringent controls on the disposal of sludge, i.e., restriction of ocean and fresh water dumping and of incinceration due to increased air quality standards, has led to a great increase in the amount of sludge being applied to the soil. The possible health effects on humans and animals resulting from the land application of sludge has not yet been fully evaluated, especially in regard to pathogenic organisms, including parasites, that might be present in sludges.

The purpose of the present study being conducted by a team of workers from Tulane University School of Public Health and Tropical Medicine is primarily to investigate selected municipal sludges in the northern portion of the United States for the presence of resistant stages of parasites. It is expected that this data along with data the team has previously collected in the southern portion of the United States will aid in the evaluation of the health risks to humans and domestic animals resulting from the land application of domestic sludges and will permit governmental agencies to formulate realistic policies regarding the land applications of sludges.

The research team of Tulane University is composed of faculty members who specialize in environmental chemistry, environmental engineering and parasitology, as well as graduate students and technicians who are working in these specialities. Tulane University is one of the few schools in the U. S. which has experts in all of these areas.

The sludge samples that we will collect will be examined for the resistant stages of parasites, i.e., eggs of tapeworm, roundworms, and flukes, and the cystic stages of protozoa. In our previous studies in the south, we have found the eggs of parasites of humans, dogs, cats, pigs, rats, poultry, and a few wild animals. We want to find out whether the same parasites are found in northern sludges and, if so, whether they are found in similar or in lower levels of concentration.

We will collect sludge samples from three different process stages when possible, i.e., before digestion, after digestion, and after dewatering. The purpose of examining these samples is to enable us to detect treatment processes that are effective in killing the parasites.

We would like to emphasize that we are not concerned with the effluent quality in any plant or with the quality of plant operation. These factors are not related to the presence or absence of parasites in sludges and we do not include them in our reports to the Environmental Protection Agency. Likewise in our reports to the EPA, the plants that we study are referred to by number only and their location is not given except for the state in which they are located.

APPENDIX B. DATA RECORD FORMS, SIC CODES, AND KEY TO SAMPLING SITES

BACKGROUND STATISTICS FOR EACH PLANT VISITED

TASK (1=Field Study) 1
1

LAB (1=Field Study) 1
2

TRIP (1=First Trip and Before) 1
3

STATE (1=Minn., 2=Ohio, 3=N.Y., 4=Wash., 5=Ala., 6=Fla., 7=La., 8=Ms., 9=Tx.) ___
4

PLANT NUMBER ___ ___
5 6

NAME OF PLANT ______________________________

GENERAL SITE (9=Background Statistics) 9
7

MAXIMUM EFFLUENT TREATMENT (1, 2 or 3) ___
8

AGE OF SYSTEM ___ ___
9 10

DESIGN CAPACITY ___ ___ ___ ___ ___ ___ MGD
11 12 13 14 15 16

SEASONAL RANGE OF FLOW: LOW ___ ___ ___ ___ ___ ___ MGD
17 18 19 20 21 22

HIGH ___ ___ ___ ___ ___ ___ MGD
23 24 25 26 27 28

POPULATION SERVED ___ ___ ___ ___ ___ ___ ___
29 30 31 32 33 34 35

ULTIMATE SLUDGE DISPOSAL: ______________________________ ___ ___
36 37

(See Key for Coding) ______________________________ ___ ___
38 39

______________________________ ___ ___
40 41

______________________________ ___ ___
42 43

INDUSTRY SERVED BY PLANT: (Use SIC Codes)

______________________________ ___ ___ ___ ___
44 45 46 47

______________________________ ___ ___ ___ ___
48 49 50 51

______________________________ ___ ___ ___ ___
52 53 54 55

______________________________ ___ ___ ___ ___
56 57 58 59

CARD ORDER ___ ___
79 80

COMMENTS ABOUT SYSTEM: ______________________________

____

APPENDIX B. (Continued)

FIELD DATA SHEET FOR EACH PLANT EACH TRIP
OVERALL INFORMATION

TASK (1,2, or 3)	$\frac{1}{1}$	
LAB (1-Field, 2-EHS, 3-Parasit)	$\frac{1}{2}$	
TRIP	___ 3	
STATE	___ 4	
PLANT	___ 5 ___ 6	
NAME OF PLANT ________________		
GENERAL SITE (Overall Information - 4)	$\frac{4}{7}$	
DATE	8 9 / 10 11 / 12 13	
TIME	14 15 : 16 17	
FLOW @ TIME OF SAMPLING	18 19 20 21 . 22 23	MGD
PREVIOUS DAY'S LOW FLOW	24 25 26 27 . 28 29	MGD
TIME	30 31 : 32 33	
PREVIOUS DAY'S HIGH FLOW	34 35 36 37 . 38 39	MGD
TIME	40 41 : 42 43	
PRECIPITATION: DAY OF SAMPLING	44 45 . 46 47	in.
WEEK BEFORE SAMPLING	48 49 . 50 51	in.
MONTH BEFORE SAMPLING	52 53 . 54 55	in.
AMBIENT TEMPERATURE: TIME OF SAMPLING	56 57 58 . 59 60	°C.
PLANT UPSET RECENTLY (0-NO, 1-YES)	61	
If yes (1), when?	62 63 / 64 65 / 66 67	
AMBIENT TEMPERATURE: DAILY HIGH	68 69 70 . 71 72	°C.
DAILY LOW	73 74 75 . 76 77	°C.
CARD ORDER	79 80	

APPENDIX B. (Continued)

FIELD DATA SHEET FOR SLUDGE SAMPLES

TASK 1, LAB 1

1 1
1 2

TRIP, STATE, PLANT NUMBER

NAME OF PLANT ____________________ 3 4 5 6

SAMPLING SITE

SAMPLING SITE ____________________ 7 8 9 10 11

TANK #

TEMPERATURE OF SAMPLE 12 13

pH OF SAMPLE 14 15 16 17 °C

REDOX OF SAMPLE 18 19 20 21 H+ conc.

22 (+ or -)

DISSOLVED OXYGEN CONTENT 23 24 25 mVolts

SAMPLE SIZE (1=1 liter, 5=5 gallons) 26 27 28 29 ppm

SAMPLE FROM TAP (0=no, 1=yes) 30

PUMPING SCHEDULE (888.888=continuous) 31

32 33 34 35 36 37 38 days

If continuous, rate pumped

39 40 41 42 gpm

If set volume, volume pumped

43 44 45 46 47 48 gallons

RETENTION TIME

49 50 51 52 53 54 55 days

DEPTH OF SLUDGE

56 57 58 59 feet

AGE OF SLUDGE

60 61 62 days

TEMP (+ or -)

63 (+ or -)

CARD ORDER

79 80

APPENDIX B. (Continued)

LABORATORY DATA SHEET FOR PARASITOLOGIC EXAMINATIONS

TASK 1, LAB 3				1 1	3 2
TRIP #, STATE #, PLANT #		3	4	5	6
NAME OF PLANT ____________________					
SAMPLING SITE ____________________					
	7	8	9	10	11
CARD NUMBER ONE					1 12
ACTUAL SAMPLE SIZE		13	14	15	16 gdw
ASCARIS viable		17	18	19	20
nonviable		21	22	23	24
T. TRICHIURA viable		25	26	27	28
nonviable		29	30	31	32
T. VULPIS viable		33	34	35	36
nonviable		37	38	39	40
TOXOCARA viable		41	42	43	44
nonviable		45	46	47	48
H. DIMINUTA viable		49	50	51	52
nonviable		53	54	55	56
H. NANA viable		57	58	59	60
nonviable		61	62	63	64
D. LATUM viable		65	66	67	68
nonviable		69	70	71	72
REPLICATION NUMBER				73	74
CARD NUMBER				79	80

APPENDIX B. (Continued).

LABORATORY DATA SHEET FOR PARASITOLOGIC EXAMS - PAGE 2

NAME OF PLANT________________________________ SAMPLING SITE ________________

TASK, LAB, TRIP, PLANT, & SAMPLING SITE FIRST ELEVEN DIGITS FROM PAGE ONE				1 1	3 2
		3	4	5	6
	7	8	9	10	11
CARD NUMBER TWO					2 12
CAPILLARIA SPP - PITS viable			13	14	15
nonviable			16	17	18
CAPILLARIA SPP - STRIATIONS viable			19	20	21
nonviable			22	23	24
TRICHOSOMOIDES-LIKE viable			25	26	27
nonviable			28	29	30
ASCARIDIA-LIKE viable			31	32	33
nonviable			34	35	36
TOXASCARIS viable			37	38	39
nonviable			40	41	42
S. MANSONI viable			43	44	45
nonviable			46	47	48
FOR FOLLOWING PROTOZOA: 1=present, 0=absent					
E.COLI-LIKE viable, nonviable				49	50
GIARDIA SPP viable, nonviable				51	52
COCCIDIA viable, nonviable				53	54
ELAPSED TIME BETWEEN COLLECTION AND READING			55	56	57
NUMBER OF SAMPLE REPITIONS				58	59
PARASCARIS viable				60	61
nonviable				62	63
TAENIID viable				64	65
nonviable				66	67
CARD ORDER				79	80

APPENDIX B. (Continued)

EHS LABORATORY DATA SHEET FOR FIELD SAMPLES

TASK (1=Field Study)	1 1	
LAB (2=Environmental Health Sciences)	2 2	
TRIP	3	
STATE	4	
PLANT NUMBER	5 6	
NAME OF PLANT ________________________		
SAMPLING SITE ________________________		
GENERAL SITE: 1=PREDIGESTION 2=POSTDIGESTION 3=FINAL SLUDGE	7	
SITE CATEGORY (See Key)	8	
SPECIFIC SITE (See Key)	9 10	
THICKENED (0=No or Dry, 1=Yes)	11	
TOTAL SUSPENDED SOLIDS	12 13 14 . 15 16 17	mg/l
TOTAL VOLATILE SOLIDS	18 19 20 . 21 22 23	mg/l
% MOISTURE	24 25 . 26 27	%
CHEMICAL OXYGEN DEMAND	28 29 30 . 31 32 33	mg/l
TOTAL KJELDAHL NITROGEN	34 35 36 . 37 38 39	mg/l
pH	40 41 . 42 43	H+ Conc.
REDOX POTENTIAL	44	(+ or -)
	45 46 47	mVolts
% VOLATILE SOLIDS	48 49 . 50 51	%
REPLICATION #	52	
FINAL SLUDGE = /	78	
CARD ORDER	79 80	

APPENDIX B. (Continued)

SIC CODES USED

2000		Food
	2010	Meat Processing - Misc.
	2011	Cattle Processing
	2012	Hog Processing
	2014	Sheep Processing
	2015	Deer Processing
	2016	Poultry Processing
	2017	Meat Rendering Plant
	2020	Dairy Processing - Misc.
	2022	Cheese Processing
	2026	Fluid Milk Processing
	2030	Fruits & Vegetables
	2033	Canned Fruits & Vegetables
	2035	Beet Sugar Processing
	2036	Fruit Juice
	2037	Soybean Processing
	2038	Corn Processing
	2039	Grape Processing
	2080	Beverages
	2082	Malt Beverages
	2086	Soft Drinks
	2090	Food Processing - Misc.
	2091	Meat Breading Plant
	2092	Fresh or Frozen Fish
2200		Textile Products
	2201	Textile Dying
	2241	Fabric Mill
2400		Lumber
	2492	Particle Board
2700		Printing & Publishing
	2750	Commercial Printing
3000		Rubber & Misc. Plastic Products
	3070	Plastic Products - Misc.
3300		Primary Metal Industries
	3325	Steel Foundries
3400		Fabricated Metal Products
	3465	Automobile Stamping
	3471	Metal Plating
	3490	Machine Shop
	3496	Fabricated Wire Products
3500		Machinery, Except Electrical
	3519	Internal Combustion Engines
3700		Transportation Equipment
	3711	Motor Vehicles & Car Bodies
8000		Health Services
	8063	Psychiatric Hospital
8200		Educational Services
	8220	College or University
888		No Industry

KEY TO THE VARIOUS SAMPLING SITE CATEGORIES

GENERAL SITE = 1 = PREDIGESTION

SITE CATEGORY = 1 = RAW OR PRIMARY	
Raw	01
Preaerated	02
Primary	03
SITE CATEGORY = 2 = PRIMARY + X	
Primary + TF Secondary	01
Primary + AS Secondary	02
Primary + ASCM Secondary	03
Primary + ASCS Secondary	04
Primary + ASEA Secondary	05
Primary + ASM Secondary	06
Primary + Pure Oxygen Secondary	07
Primary + Return Sludge	08
Primary + Flocculation Tank	09
SITE CATEGORY = 3 = ACTIVATED SLUDGE	
Activated Sludge	02
Activated Sludge Complete Mix	03
Activated Sludge Contact Stabilized	04
Activated Sludge Extended Aeration	05
Activated Sludge Modified	06
Activated Sludge Pure Oxygen	07
Return Sludge	08
Flocculation Tank	09
SITE CATEGORY = 4 = STORED PRIMARY	
Stored Primary	01
SITE CATEGORY = 5 = CHEMICAL	
Pure Fax	01
Limed Sludge	02
Chemical Sludge	03

GENERAL SITE = 2 = POSTDIGESTIONS

SITE CATEGORY = 1 = AEROBIC DIGESTION	
Mesophilic	01
Thermomphilic	02
Thermoduric	03
SITE CATEGORY = 2 - ANAEROBIC DIGESTION	
Mesophilic	01
Thermophilic	02
Thermoduric	03
Primary to Secondary Mesophilic	04
Primary to Secondary Thermophilic	05
Primary to Secondary Thermoduric	06
Primary Mesophilic Supernatant	07
SITE CATEGORY = 3 = IMHOFF DIGESTION	
Imhoff	01
SITE CATEGORY = 4 = STORED DIGESTED	
Stored	01
SITE CATEGORY = 5 = ZEM PRO	
Zem Pro	01
SITE CATEGORY = 6 = CHEMICAL	
Ferric + Lime Flocculator	01
Polymer Flocculatar	02

GENERAL SITE = 3 = FINAL SLUDGE

SITE CATEGORY = 1 = BIOLOGICAL	
Drying Bed	01
Covered Drying Bed	02
Compost	03
Stored & Piled Drying Bed	04
SITE CATEGORY = 2 = MECHANICAL	
Vacuum Filter	01
Centrifuge	02
Incinerator	03
SITE CATEGORY = 3 = LAGOONED	
Lagoon	01
Limed Lagoon	02

APPENDIX B. (Continued)

KEY TO ULTIMATE SLUDGE DISPOSAL

CHURCHYARDS	01
GOLF COURSES	02
HIGHWAY MEDIANS	03
IRRIGATION OF CROPLAND	04
IRRIGATION OF PASTURES	05
LAGOONS	06
LAND RECLAMATION	07
LANDFILL	08
PLANT NURSERIES	09
PARKS	10
PUBLIC USE AT HOME	11
SCHOOLYARDS	12
SOLD COMMERCIALLY	13
SOLD TO COMMERCIAL DEALERS	14
TRUCK GARDENS	15
WORM FARMS	16
LIQUID FERTILIZER FOR CROPLAND	17
LIQUID FERTILIZER FOR PASTURES	18
DRY FERTILIZER FOR CROPLAND	19
DRY FERTILIZER FOR PASTURES	20
BARGED TO OCEAN	21
LAWNS OF PRIVATE INDUSTRIES	22
TREE FARMS	23
INCINERATED PRIOR TO LANDFILL	24
USED ON CITY PROPERTY	25
STOCKPILED AT PLANT AT PRESENT	26

APPENDIX C

Procedures for Parasitologic Examination of Waste Sludges

Reagents

1. 1% of soln (v/v) of "7X", an anionic detergent
2. $ZnSO_4$ soln, specific gravity 1.20, adjusted with hydrometer
3. Alcohol - Acid Soln; 35% Ethyl Alcohol +0.27% (v/v) H_2SO_4
4. Ether - Anhydrous
5. Siliclad (Clay Adams), for coating glassware with silicone

Materials

1. Beakers, 1000 ml., tall form, Berselius, Pyrex
2. Beakers, 1000 ml., low form, Kimax
3. Sieves, 5 in., gauges 10, 20, 50, 100, and 150
4. Funnel, powder filling, 150 mm, Nalgene
5. Applicator sticks, wooden
6. Centrifuge tubes, conical, polypropylene, 50 ml
7. Centrifuge tubes, conical, "Pyrex", 15 ml
8. Pipettes, Pasteur, disposable, 5-3/4 in.
9. Microscope slides, 3 x 2 in.
10. Cover glasses, 22 x 30, 24 x 40, 24 x 50 mm
11. Wash bottles, plastic, 500 ml and 1000 ml
12. Aspirator carboys, 8 l, Nalgene
13. Aspirator, bottle, 4 l, Nalgene

Equipment

1. Centrifuge, IEC, with head and cups for 50 ml tubes
2. Centrifuge, Clinical model, with head for 15 ml conical tubes
3. Magnetic Stirrer
4. Ultrasonic cleaner, 11-1/2" x 5-1/2" x 6"
5. Vortex mixer
6. Blender, with 1 l container
7. Microscope, Compound, A.O.
8. Balance, Double Beam, Harvard

Procedures

A. Thickened Sludges

1. Place 100 ml of sample in 1000 ml beaker, low form.
2. Add about 250-300 ml of 1% soln of "7X" and mix for at least 5 min. or magnetic stirrer.
3. Strain homogenized sample through the following series of sieves; 10, 20, 50, 100 and 150. Sieves placed on funnel over another 1000 ml beaker and sample washed through each sieve with aid of stream from a wash bottle containing 1% "7X".
4. After sample has been passed through each sieve it is placed in a 1000 ml beaker, tall form, and allowed to settle for at least one hour.
5. Supernatant is decanted and discarded; sediment is then placed in a 50 ml centrifuge tube (more if necessary).
6. Sample is centrifuged at 800 g for at least 2 min. and supernatant is poured off.
7. If packed volume of sediment is 7-8 ml or less, proceed as below; if volume is more than this, the sediment should be resuspended in tap water evenly divided between 2 cubes, and centrifuged as above.
8. Add $ZnSO_4$ soln. to packed sediment, mix thoroughly with applicator sticks, increase volume to 50 ml and centrifuge at 800 g for 3 min.

9. After centrifuge has come to a full stop without breaking and solution in tubes has stopped swirling, pour top 30 to 40 ml of supernatant in each tube into a 400 ml beaker. During pouring off of supernatant, rotate tube in order to allow all of material floating on surface to be poured off with supernatant.

10. Dilute poured off supernatant to about 250 ml with tap water.

11. Place diluted supernatant in 6 or more 50 ml tubes and centrifuge at 800 g for 3 min.

12. Discard supernatant by pouring off and transfer sediment to one or more 15 ml centrifuge tubes, using stream of tap water from a wash bottle to completely wash all of sediment from each tube. Fill to near top with tap water.

13. Centrifuge at 800 g for 3 min., discard supernatant. If more than one tube is used, combine sediment into one tube unless combined sediment would exceed 1.5 ml.

14. Add 10 ml of alcohol-acid solutions to sediment (packed sediment should not exceed 1.5 ml, if so, divide sediment into 2 or more tubes), and mix thoroughly with applicator stick.

Steps 15-17 should be carried out under a hood

15. Add 3 ml of ether, place rubber stopper in tube, and mix by shaking vigorously for 15 sec.

16. Remove stopper and centrifuge at 800 g for 3 min. at full speed.

17. Use applicator stick to ring tube to free plug at ether alcohol-acid interface, and pour off entire supernatant into safety can by quickly inverting the tube.

18. Transfer sediment to one or more slides, cover with appropriate size of cover glass and examine under at least 100 x magnification of compound microscope.

19. Count each type of helminth egg and note whether eggs appear to be viable or whether they appear to be dead (non-viable). Note presence of protozoan cysts, if any, and indicate type.

20. For reporting, convert counts to number of organisms per gram or kilogram of dry weight.

B. Dried Sludges (i.e., from drying beds or dewatering units)

1. Weigh out a sample of 30 gm and place in a 1000 ml beaker and add about 300 ml of tap water; allow to stand overnight.

2. Place sample in blender and blend until thoroughly homogenized; transfer to 1000 ml beaker and add tap water until volume is about 900 ml.

3. Allow to settle for 1 hr. or more.

4. Decant and add 1% "7X" until beaker is nearly full.

5. Allow to settle for 1 hr. or more.

6. Decant and place beaker with sediment on a magnetic stirrer (use 2 in. stirring bar in beaker) for 5 min.

7. Add 1% "7X" until beaker is nearly full and allow to settle for 1 hr. or more.

8. Decant and pass sediment through series of sieves as in A3 (above) and follow procedure given in A4 through A20.

C. Dilute Sludges (i.e., with low solid content)

1. Place measured amount of sample in 1000 ml beaker and allow to settle for at least 1 hr. Amount used initially to depend on amount of solids and in the case of very dilute samples more than 1000 ml of sample may need to be sedimented.

2. Decant supernatant and proceed as with A3 to A20 above.

D. Cultivation of Eggs

1. To sediment obtained in Steps 1 through 17 of Procedure A, add 2-3 ml of culture fluid (0.27% H_2SO_4, v/v) to tubes, mix on vortex mixer, then bring volume to 15 ml by adding more culture fluid.

2. Centrifuge for 3 minutes at 800 g and pour off supernatant.

3. Add a few drops of culture fluid to sediment, mix with clean pipette, and transfer to culture dish. Rinse tube and pipette with a 1 ml or less of culture fluid. Add additional culture fluid to culture dish, if necessary, to bring depth of fluid to 3 to 4 mm.

4. Cover culture dishes and store in dark or subdued light at 22-28C. Dishes should be agitated every few days to mix sediment and aerate fluid.

5. After a minimum of 21 days, the cultured sample is transferred to one or more 15 ml conical centrifuge tubes depending on volume of sample.

6. Centrifuge at 800 g for 3 minutes and then pour off supernatant.

7. With pipette, transfer sediment to one or more slides for microscopic examination. Transfer appropriate amount of sediment for size of coverglass (20 x 30 mm or 22 x 40 mm recommended). Fluid should not extend beyond edge of coverglass.

8. Systematically examine each preparation under at least 100 x magnification of a compound, binocular microscope.

9. Count all Ascaris eggs present and record whether they contain a developed larva (viable) or are undeveloped (nonviable); also record numbers of all other helminth eggs present and their state of development.

GENERAL COMMENTS

After each use, sieves are washed thoroughly and placed in an ultrasonic cleaner containing appropriate detergent for at least 10 minutes.

In sediments from some anaerobic sludges, the eggs of helminths are darkly stained and difficult to identify when examined microscopically. In such cases, they are bleached slightly by treating with a 2% dilution of commercial bleach (Clorox) for a few minutes then washed again in water before examination.

Glassware should be coated with Siliclad at appropriate intervals.

APPENDIX D. RESULTS OF FIELD STUDIES

THE STATE OF MINNESOTA: PLANT 101

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
1000000	250.00	150.00	400.00	7	SECONDARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
METAL PLATING MISC HEAT PROCESS MALT BEVERAGES	LAGOONS DRY FERT. CROPS

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	PH	REDOX (mVs)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	PRIMARY & ACTIVATED	38320	25920	61600	1288	5.6	-155	N.D.	N.D.
TRIP 2	PRIMARY & ACTIVATED	122050	72750	131200	1624	5.8	-210	N.D.	N.D.
TRIP 3	PRIMARY & ACTIVATED	53300	33900	196000	1319	5.8	-100	N.D.	N.D.
TRIP 1	STORED PRIMARY	47240	33280	96400	1568	5.3	-160	N.D.	N.D.
TRIP 2	STORED PRIMARY	78750	45500	108400	2800	6.1	-179	N.D.	N.D.
TRIP 3	STORED PRIMARY	45030	26740	192000	1405	6.2	-100	N.D.	N.D.
TRIP 1	VACUUM FILTER	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	67.5	64.9
TRIP 2	VACUUM FILTER	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	63.4	56.3
TRIP 3	VACUUM FILTER	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	22.8	45.9

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	PRIMARY & ACTIVATED	263	526	0	0	0	0	526	526
TRIP 2	PRIMARY & ACTIVATED	205	574	0	123	41	41	451	492
TRIP 3	PRIMARY & ACTIVATED	1132	1132	189	189	0	0	377	377
TRIP 1	STORED PRIMARY	638	638	851	851	426	426	426	426
TRIP 2	STORED PRIMARY	362	771	172	398	63	63	1161	1460
TRIP 3	STORED PRIMARY	444	888	222	222	0	0	222	222
TRIP 1	VACUUM FILTER	206	310	0	0	0	0	0	206
TRIP 2	VACUUM FILTER	137	779	0	46	0	92	46	275
TRIP 3	VACUUM FILTER	147	147	49	49	0	0	49	98

THE STATE OF MINNESOTA: PLANT 103

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
1641	.30	.04	.80	20	PRIMARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
CATTLE PROCESSING HOG PROCESSING POULTRY PROCESSING	DRY FERT. CROPS

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	PH	REDOX (MV)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	SETTLED PRIMARY	37520	33400	77600	952	5.7	-175	N.D.	N.D.
TRIP 2	SETTLED PRIMARY	37200	27650	59200	1512	5.6	-130	N.D.	N.D.
TRIP 3	SETTLED PRIMARY	52850	38100	164000	1415	6.2	-140	N.D.	N.D.
TRIP 2	MESO ANAEROBIC DIG	2140	1560	5600	1568	7.2	-190	N.D.	N.D.
TRIP 3	1 TO 2 MESO AN DIG	2400	1750	15000	1102	7.4	-110	N.D.	N.D.
TRIP 1	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	81.9	49.8
TRIP 2	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	69.4	49.9
TRIP 3	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	62.9	51.0

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	SETTLED PRIMARY	250	250	750	750	250	250	0	0
TRIP 2	SETTLED PRIMARY	405	1081	0	0	0	0	405	540
TRIP 3	SETTLED PRIMARY	189	378	0	0	0	0	377	754
TRIP 2	MESO ANAEROBIC DIG	2500	7500	0	0	0	0	0	5000
TRIP 3	1 TO 2 MESO AN DIG	5000	5000	0	0	0	0	0	0
TRIP 1	DRYING BED	0	0	128	128	0	0	128	128
TRIP 2	DRYING BED	108	163	0	0	0	0	108	217
TRIP 3	DRYING BED	0	0	0	0	0	0	0	0

APPENDIX D. (Continued)

THE STATE OF MINNESOTA: PLANT 135

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
8	.05	.05	.08	27	PRIMARY TREATMENT

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	pH	REDOX (mvs)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 2	RAW INFLUENT	2440	1900	298	2184	6.8	-160	N.D.	N.D.
TRIP 3	RAW INFLUENT	3250	2150	15000	1414	6.7	-180	N.D.	N.D.
TRIP 1	IMHOFF DIGESTION	57820	45920	95200	1568	5.1	-100	N.D.	N.D.
TRIP 2	IMHOFF DIGESTION	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	88.1	76.2
TRIP 3	IMHOFF DIGESTION	245250	232300	110000	8	6.0	-120	N.D.	N.D.
TRIP 1	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	58.1	49.4
TRIP 2	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	51.6	8
TRIP 3	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	68.5	88.5

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 2	RAW INFLUENT	0	0	0	0	0	0	4000	4000
TRIP 3	RAW INFLUENT	0	0	0	0	0	0	0	0
TRIP 1	IMHOFF DIGESTION	0	0	0	0	0	0	690	1207
TRIP 2	IMHOFF DIGESTION	0	0	0	0	0	0	694	1805
TRIP 3	IMHOFF DIGESTION	0	0	0	0	0	0	225	225
TRIP 1	DRYING BED	333	3083	0	0	0	0	83	250
TRIP 2	DRYING BED	0	517	0	0	0	0	0	297
TRIP 3	DRYING BED	0	0	0	0	0	0	0	0

APPENDIX D. (Continued)

THE STATE OF MINNESOTA: PLANT #106

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
11940	1.30	.86	1.78	24	SECONDARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
PARTICLE BOARD	LIQUID FERT. CROPS DRY FERT. CROPS PUBLIC USE AT HOME

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	pH	REDOX IN (mVs)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	SETTLED PRIMARY	50080	32460	69600	1232	6.8	-208	N.D.	N.D.
TRIP 2	SETTLED PRIMARY	46400	29500	79200	1456	6.2	-190	N.D.	N.D.
TRIP 3	SETTLED PRIMARY	45800	32750	125000	1242	6.5	-160	N.D.	N.D.
TRIP 1	MESO ANAEROBIC DIG	33280	18520	43200	1448	6.9	-205	N.D.	N.D.
TRIP 2	MESO ANAEROBIC DIG	28250	15550	28800	1008	6.2	-200	N.D.	N.D.
TRIP 3	MESO ANAEROBIC DIG	36000	18700	79000	1212	7.2	-190	N.D.	N.D.
TRIP 1	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	56.3	46.7
TRIP 2	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	43.8	43.0

APPENDIX D. (Continued)

THE STATE OF MINNESOTA: PLANT #106 CONT.

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	SETTLED PRIMARY	800	800	0	0	0	0	600	600
TRIP 2	SETTLED PRIMARY	0	0	0	108	0	0	326	326
TRIP 3	SETTLED PRIMARY	0	0	0	0	0	0	435	435
TRIP 1	MESO ANAEROBIC DIG	606	909	0	0	0	0	1212	2121
TRIP 2	MESO ANAEROBIC DIG	535	535	0	0	0	0	357	535
TRIP 3	MESO ANAEROBIC DIG	0	0	0	0	0	0	278	556
TRIP 1	DRYING BED	90	180	0	0	0	0	180	360
TRIP 2	DRYING BED	60	60	0	31	0	0	31	300

APPENDIX D. (Continued)

THE STATE OF MINNESOTA: PLANT 111

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
4500	.90	.30	2.30	5	SECONDARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
CATTLE PROCESSING	LIQUID FERT. CROPS
HOG PROCESSING	LIQUID FERT PASTURE
CANNED FRTS & VEGS	
DAIRY PROCESSING	

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	pH	REDOX (mVs)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	SETTLED PRIMARY	57700	42600	72000	1560	5.9	-200	N.D.	N.D.
TRIP 2	SETTLED PRIMARY	44200	27450	58400	1624	5.8	-200	N.D.	N.D.
TRIP 3	SETTLED PRIMARY	53200	23850	135000	1292	6.5	-200	N.D.	N.D.
TRIP 1	1 TO 2 MESO AN DIG	30620	15500	33600	718	7.6	-180	N.D.	N.D.
TRIP 2	1 TO 2 MESO AN DIG	21900	11450	18800	841	7.3	-170	N.D.	N.D.
TRIP 3	1 TO 2 MESO AN DIG	40400	20200	87000	923	7.5	-190	N.D.	N.D.

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	SETTLED PRIMARY	2414	2414	172	172	0	0	0	0
TRIP 2	SETTLED PRIMARY	1371	3048	113	113	0	0	0	113
TRIP 3	SETTLED PRIMARY	943	943	0	0	0	0	0	189
TRIP 1	1 TO 2 MESO AN DIG	968	968	0	323	0	0	323	323
TRIP 2	1 TO 2 MESO AN DIG	6364	9773	0	0	0	0	0	455
TRIP 3	1 TO 2 MESO AN DIG	3750	5000	250	250	0	0	0	0

APPENDIX D. (Continued)

THE STATE OF MINNESOTA: PLANT 112

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
5000	1.40	.21	3.00	1	SECONDARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
FRUIT JUICE BEET SUGAR MAKING MISC. PLASTIC PROD.	INCINERATE &LANDFILL

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	pH	REDOX (mVs)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	ACT SL PURE O2	25000	20640	41600	N	5.4	-150	N.D.	N.D.
TRIP 2	ACT SL PURE O2	33800	27000	46400	1211	5.9	-170	N.D.	N.D.
TRIP 3	ACT SL PURE O2	28850	22450	93000	N	6.0	-140	N.D.	N.D.
TRIP 1	MESO AEROBIC DIG	14100	10000	19200	N	7.1	-201	N.D.	N.D.
TRIP 2	MESO AEROBIC DIG	15000	10500	21600	1613	6.7	-210	N.D.	N.D.
TRIP 3	MESO AEROBIC DIG	18750	14000	112000	N	6.5	-170	N.D.	N.D.

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	ACT SL PURE O2	0	0	400	400	0	0	0	0
TRIP 2	ACT SL PURE O2	0	0	0	0	0	0	441	441
TRIP 3	ACT SL PURE O2	0	0	357	357	0	0	2143	2143
TRIP 1	MESO AEROBIC DIG	0	0	0	0	0	0	0	714
TRIP 2	MESO AEROBIC DIG	0	0	0	0	0	0	625	625
TRIP 3	MESO AEROBIC DIG	0	0	0	0	0	0	1053	1053

APPENDIX D. (Continued)

THE STATE OF MINNESOTA: PLANT 113

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
45000	5.00	2.00	20.00	7	SECONDARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
SOYBEAN PROCESSING METAL PLATING SOF DRINKS	LIQUID FERT. CROPS

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	pH	REDOX (mv)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	PRIM & AS COMP-MIX	40850	32000	56800	1792	6.7	-250	N.D.	N.D.
TRIP 2	PRIM & AS COMP-MIX	37750	28200	45600	2184	6.0	-180	N.D.	N.D.
TRIP 3	PRIMARY & ACTIVATED	50700	34400	177000	N	6.3	-170	N.D.	N.D.
TRIP 1	1 TO 2 MESO AN DIG	33450	18950	28000	2016	7.3	-250	N.D.	N.D.
TRIP 2	1 TO 2 MESO AN DIG	18200	10500	21600	1261	7.4	-150	N.D.	N.D.
TRIP 3	1 TO 2 MESO AN DIG	6850	4450	20000	N	7.5	-210	N.D.	N.D.
TRIP 1	LAGOON	22400	18900	64800	1176	7.0	-276	N.D.	N.D.
TRIP 2	LAGOON	18350	11900	20800	1345	7.4	-180	N.D.	N.D.
TRIP 3	LAGOON	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	68.0	68.9

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	PRIM & AS COMP-MIX	0	0	244	244	0	0	244	244
TRIP 2	PRIM & AS COMP-MIX	131	131	0	0	0	131	131	131
TRIP 3	PRIMARY & ACTIVATED	0	0	0	0	0	0	196	196
TRIP 1	1 TO 2 MESO AN DIG	0	0	274	274	0	0	882	882
TRIP 2	1 TO 2 MESO AN DIG	556	1389	0	278	0	0	0	1666
TRIP 3	1 TO 2 MESO AN DIG	0	0	0	0	0	0	1429	1429
TRIP 1	LAGOON	0	0	0	0	0	0	938	1231
TRIP 2	LAGOON	278	556	0	278	0	0	0	0
TRIP 3	LAGOON	104	104	0	0	0	0	0	104

APPENDIX D. (Continued)

THE STATE OF MINNESOTA: PLANT 114

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
650	.03	.04	.09	40	PRIMARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
NO INDUSTRY PRESENT	DRY FERT. CROPS

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS IN mg/L	TOTAL VOLATILE SOLIDS IN mg/L	CHEMICAL OXYGEN DEMAND IN mg/L	TOTAL KJEDAHL NITROGEN IN mg/L	pH	REDOX IN mVOLTS	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 2	RAW INFLUENT	205	145	80	N	7.3	-140	N.D.	N.D.
TRIP 3	RAW INFLUENT	2600	2400	13000	N	6.9	-240	N.D.	N.D.
TRIP 1	IMHOFF DIGESTION	143840	62140	95600	1176	6.3	-235	N.D.	N.D.
TRIP 2	IMHOFF DIGESTION	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	76.7	40.6
TRIP 3	IMHOFF DIGESTION	130450	57900	187000	N	6.7	-200	N.D.	N.D.
TRIP 1	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	34.5	73.1
TRIP 2	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	45.2	40.3
TRIP 3	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	55.4	59.7

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 2	RAW INFLUENT	0	0	0	0	0	0	0	0
TRIP 3	RAW INFLUENT	0	0	0	0	0	0	1538	1538
TRIP 1	IMHOFF DIGESTION	0	0	0	0	0	0	833	1458
TRIP 2	IMHOFF DIGESTION	143	214	0	535	0	0	500	2785
TRIP 3	IMHOFF DIGESTION	0	0	76	76	0	0	229	611
TRIP 1	DRYING BED	0	0	0	0	0	55	0	0
TRIP 2	DRYING BED	0	38	0	0	0	0	213	244
TRIP 3	DRYING BED	73	73	0	0	0	0	149	149

APPENDIX D. (Continued)

THE STATE OF MINNESOTA: PLANT   115

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
53000	12.60	8.76	16.00	11	SECONDARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
DAIRY PROCESSING	LIQUID FERT. CROPS

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	pH	REDOX (mVs)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	SETTLED PRIMARY	36450	20100	55200	2240	5.8	-205	N.D.	N.D.
TRIP 2	SETTLED PRIMARY	14450	11600	26000	1000	5.9	-130	N.D.	N.D.
TRIP 3	SETTLED PRIMARY	34050	23750	108000	M	5.9	-150	N.D.	N.D.
TRIP 1	1 TO 2 MESO AN DIG	22750	11250	26400	1120	7.3	-140	N.D.	N.D.
TRIP 2	1 TO 2 MESO AN DIG	10150	5900	11600	1110	7.1	-170	N.D.	N.D.
TRIP 3	1 TO 2 MESO AN DIG	14000	8350	43000	M	7.5	-150	N.D.	N.D.
TRIP 1	LAGOON	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	85.8	46.9
TRIP 2	LAGOON	37800	19700	33600	1200	7.2	-190	N.D.	N.D.
TRIP 3	LAGOON	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	68.0	M

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	SETTLED PRIMARY	270	270	0	0	0	0	811	811
TRIP 2	SETTLED PRIMARY	333	333	0	0	666	666	1333	1333
TRIP 3	SETTLED PRIMARY	294	294	0	0	0	0	0	294
TRIP 1	1 TO 2 MESO AN DIG	1304	1304	0	435	870	870	2174	2174
TRIP 2	1 TO 2 MESO AN DIG	500	1000	0	0	0	0	2500	3000
TRIP 3	1 TO 2 MESO AN DIG	2000	2667	0	0	1333	1333	667	667
TRIP 1	LAGOON	286	286	0	0	0	571	1714	3428
TRIP 2	LAGOON	789	789	131	131	789	1052	2552	4078
TRIP 3	LAGOON	0	0	0	0	49	49	98	98

APPENDIX D. (Continued)

THE STATE OF MINNESOTA: PLANT 11a

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
1090	.25	.12	.33	4	SECONDARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
CHEESE PROCESSING	LIQUID FERT. CROPS

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	PH	REDOX (mVs)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	ACT SL COMP-MIX	31550	22600	49600	1848	6.8	-225	N.D.	N.D.
TRIP 2	ACT SL COMP-MIX	25750	19900	38400	1610	5.8	-140	N.D.	N.D.
TRIP 3	ACT SL COMP-MIX	27750	18750	74000	N	6.8	-160	N.D.	N.D.
TRIP 1	MESO AEROBIC DIG	34100	24050	37200	1176	7.1	-204	N.D.	N.D.
TRIP 2	MESO AEROBIC DIG	24250	18350	27600	1310	6.5	-180	N.D.	N.D.
TRIP 3	MESO AEROBIC DIG	24400	16700	63000	N	6.7	-140	N.D.	N.D.

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	ACT SL COMP-MIX	0	0	0	0	0	0	0	0
TRIP 2	ACT SL COMP-MIX	0	0	0	0	0	0	0	0
TRIP 3	ACT SL COMP-MIX	0	0	0	0	0	0	357	357
TRIP 1	MESO AEROBIC DIG	0	294	0	0	0	0	294	294
TRIP 2	MESO AEROBIC DIG	298	298	0	0	0	0	0	0
TRIP 3	MESO AEROBIC DIG	0	0	0	0	0	0	833	833

APPENDIX D. (Continued)

THE STATE OF MINNESOTA: PLANT 117

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
40000	6.50	2.50	14.50	7	SECONDARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
METAL PLATING MALT BEVERAGES	CITY PROPERTIES LANDFILL

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	pH	REDOX (mV)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	SETTLED PRIMARY	44150	33550	66400	2352	5.4	-157	N.D.	N.D.
TRIP 2	SETTLED PRIMARY	32850	27250	52000	1510	5.2	-100	N.D.	N.D.
TRIP 3	SETTLED PRIMARY	40850	31800	167000	N	5.9	-130	N.D.	N.D.
TRIP 1	1 TO 2 MESO AN DIG	55950	30950	28800	1600	7.6	-184	N.D.	N.D.
TRIP 2	1 TO 2 MESO AN DIG	17600	10900	20400	913	7.1	-130	N.D.	N.D.
TRIP 3	1 TO 2 MESO AN DIG	4550	3100	17000	N	7.2	-180	N.D.	N.D.
TRIP 1	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	51.0	N
TRIP 2	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	40.6	36.9
TRIP 3	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	53.4	57.7

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	SETTLED PRIMARY	0	0	0	0	0	0	1591	1591
TRIP 2	SETTLED PRIMARY	0	0	151	151	0	0	0	0
TRIP 3	SETTLED PRIMARY	0	0	0	0	0	0	1463	1463
TRIP 1	1 TO 2 MESO AN DIG	0	536	0	0	893	1072	179	2858
TRIP 2	1 TO 2 MESO AN DIG	0	0	0	0	0	0	0	1944
TRIP 3	1 TO 2 MESO AN DIG	0	0	0	0	0	0	2000	2000
TRIP 1	DRYING BED	45	45	0	0	0	0	261	453
TRIP 2	DRYING BED	0	28	0	0	0	28	0	54
TRIP 3	DRYING BED	0	0	0	0	0	0	0	0

APPENDIX D. (Continued)

THE STATE OF OHIO: PLANT 203

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
25000	4.00	2.00	30.00	23	SECONDARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
CATTLE PROCESSING HOG PROCESSING FISH PROCESSING	PUBLIC USE AT HOME SOLD TO DEALERS

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	PH	REDOX (mv)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	SETTLED PRIMARY	57100	34600	57600	2184	4.9	-150	N.D.	N.D.
TRIP 2	SETTLED PRIMARY	79300	44650	48247	N	5.4	-170	N.D.	N.D.
TRIP 3	SETTLED PRIMARY	83300	41350	138000	N	5.4	-240	N.D.	N.D.
TRIP 1	1 TO 2 MESO AN DIG	55750	23050	44800	984	6.7	-120	N.D.	N.D.
TRIP 2	1 TO 2 MESO AN DIG	17450	8850	10934	N	6.7	-160	N.D.	N.D.
TRIP 3	1 TO 2 MESO AN DIG	61550	24800	127000	N	7.4	-230	N.D.	N.D.
TRIP 1	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	28.9	16.9
TRIP 2	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	39.9	13.2
TRIP 3	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	82.9	37.4
	STORED DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	45.5	75.6

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	SETTLED PRIMARY	175	175	175	175	1053	1053	1228	2105
TRIP 2	SETTLED PRIMARY	506	506	0	0	0	0	1646	1646
TRIP 3	SETTLED PRIMARY	241	241	0	0	3253	3253	2048	2048
TRIP 1	1 TO 2 MESO AN DIG	0	0	179	179	536	536	714	893
TRIP 2	1 TO 2 MESO AN DIG	0	0	0	0	2353	2353	2329	4705
TRIP 3	1 TO 2 MESO AN DIG	161	161	0	0	1290	1613	2097	3065
TRIP 1	DRYING BED	94	94	0	0	0	0	47	47
TRIP 2	DRYING BED	278	722	0	0	111	222	111	222
TRIP 3	DRYING BED	0	1731	0	0	1346	1731	0	2115
	STORED DRYING BED	41	204	0	0	245	306	0	920

APPENDIX D. (Continued)

THE STATE OF OHIO: . PLANT 205

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
2290	.82	.20	1.60	12	SECONDARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
AUTOMOTIVE STAMPING CATTLE PROCESSING	PUBLIC USE AT HOME

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	pH	REDOX (mV)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	SETTLED PRIMARY	43550	26350	61600	1456	6.2	-220	N.D.	N.D.
TRIP 2	SETTLED PRIMARY	944	644	3360	N	6.9	-220	N.D.	N.D.
TRIP 3	SETTLED PRIMARY	51350	39550	N	N	6.7	-210	N.D.	N.D.
TRIP 1	MESO ANAEROBIC DIG	122300	40650	83200	560	7.0	-200	N.D.	N.D.
TRIP 3	MESO ANAEROBIC DIG	4730	2290	12090	N	7.3	-160	N.D.	N.D.
TRIP 1	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	67.3	34.6
TRIP 2	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	44.8	21.2
TRIP 3	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	59.5	25.6

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	SETTLED PRIMARY	1818	2945	909	909	455	455	2955	2955
TRIP 2	SETTLED PRIMARY	0	0	0	0	0	0	5000	5000
TRIP 3	SETTLED PRIMARY	1961	2353	0	392	0	0	1176	1372
TRIP 1	MESO ANAEROBIC DIG	738	1230	164	164	0	82	246	738
TRIP 3	MESO ANAEROBIC DIG	6000	12000	0	0	2000	2000	0	0
TRIP 1	DRYING BED	306	1326	102	102	0	0	102	408
TRIP 2	DRYING BED	120	240	0	0	60	60	60	482
TRIP 3	DRYING BED	1311	2377	82	82	164	246	246	574

APPENDIX D. (Continued)

THE STATE OF OHIO: PLANT 20a

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
55000	33.00	6.00	53.00	1	SECONDARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
CATTLE PROCESSING DAIRY PROCESSING INT. COMBUST. ENG.	LIQUID FERT. CROPS SOLD TO DEALERS

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	PH	REDOX (mVs)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	SETTLED PRIMARY	74600	29400	54400	3136	6.2	-120	N.D.	N.D.
TRIP 2	SETTLED PRIMARY	119150	41000	38400	N	6.2	-135	N.D.	N.D.
TRIP 3	SETTLED PRIMARY	69850	23050	92000	N	6.9	-210	N.D.	N.D.
TRIP 1	1 TO 2 MESO AN DIG	105300	36650	73000	1736	6.9	-165	N.D.	N.D.
TRIP 2	1 TO 2 MESO AN DIG	83400	31300	28267	N	6.6	-90	N.D.	N.D.
TRIP 1	STORED DIGESTED	135100	44750	84000	1796	6.9	-175	N.D.	N.D.
TRIP 2	STORED DIGESTED	95760	32000	60267	N	6.8	-135	N.D.	N.D.
TRIP 3	STORED DIGESTED	134950	40850	161000	N	7.2	-200	N.D.	N.D.

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	SETTLED PRIMARY	533	800	0	0	533	533	1600	1733
TRIP 2	SETTLED PRIMARY	336	336	84	84	84	84	588	840
TRIP 3	SETTLED PRIMARY	286	286	0	0	714	714	571	857
TRIP 1	1 TO 2 MESO AN DIG	381	381	0	95	95	95	1143	1714
TRIP 2	1 TO 2 MESO AN DIG	482	482	0	0	0	0	963	1445
TRIP 1	STORED DIGESTED	370	444	74	74	963	963	370	963
TRIP 2	STORED DIGESTED	1042	1355	313	417	625	625	938	1251
TRIP 3	STORED DIGESTED	296	296	0	0	0	0	74	148

APPENDIX D. (Continued)

THE STATE OF OHIO: PLANT 207

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
450	.08	N	N	40	PRIMARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
NO INDUSTRY PRESENT	DRY FERT. PASTURES

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	pH	REDOX (mv)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	RAW INFLUENT	2160	1740	12000	1200	6.6	-155	N.D.	N.D.
TRIP 2	RAW INFLUENT	182	120	64	N	6.7	-130	N.D.	N.D.
TRIP 3	RAW INFLUENT	1260	700	7000	N	7.2	-330	N.D.	N.D.
TRIP 1	IMHOFF DIGESTION	203250	46450	96000	1616	5.5	-140	N.D.	N.D.
TRIP 2	IMHOFF DIGESTION	177250	64100	8800	N	6.7	-130	N.D.	N.D.
TRIP 3	IMHOFF DIGESTION	130650	63350	N	N	5.8	-260	N.D.	N.D.

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	RAW INFLUENT	0	0	0	0	0	0	0	0
TRIP 2	RAW INFLUENT	0	0	0	0	0	0	100000	100000
TRIP 3	RAW INFLUENT	0	0	0	0	0	0	0	0
TRIP 1	IMHOFF DIGESTION	0	49	0	49	0	49	99	296
TRIP 2	IMHOFF DIGESTION	56	451	0	113	56	169	169	395
TRIP 3	IMHOFF DIGESTION	0	382	0	76	305	458	76	916

APPENDIX D. (Continued)

THE STATE OF OHIO: PLANT 208

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
270000	75.00	35.00	105.00	7	SECONDARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
METAL PLATING	LAGOONS

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	pH	REDOX (mV)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	SETTLED PRIMARY	64000	44250	92000	1456	5.8	-135	N.D.	N.D.
TRIP 2	SETTLED PRIMARY	46000	36750	41867	N	5.3	-225	N.D.	N.D.
TRIP 3	SETTLED PRIMARY	56050	34050	163000	N	6.1	-210	N.D.	N.D.
TRIP 1	1 TO 2 MESO AN DIG	27050	13600	28000	546	7.3	-140	N.D.	N.D.
TRIP 2	MESO ANAEROBIC DIG	25050	13400	7200	N	6.9	-230	N.D.	N.D.
TRIP 3	MESO ANAEROBIC DIG	45150	21800	94000	N	7.6	-200	N.D.	N.D.

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	SETTLED PRIMARY	156	156	0	0	156	156	625	625
TRIP 2	SETTLED PRIMARY	217	217	0	0	435	435	870	870
TRIP 3	SETTLED PRIMARY	0	0	0	0	179	179	179	179
TRIP 1	1 TO 2 MESO AN DIG	0	0	0	0	357	357	357	357
TRIP 2	MESO ANAEROBIC DIG	800	800	400	400	0	0	2400	2400
TRIP 3	MESO ANAEROBIC DIG	0	0	0	0	0	0	1333	1535

APPENDIX D. (Continued)

THE STATE OF OHIO: PLANT 209

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGD	SEASONAL LOW FLOW IN MGD	SEASONAL HIGH FLOW IN MGD	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
1000	N	N	N	8	SECONDARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
CATTLE PROCESSING HOG PROCESSING SHEEP PROCESSING DEER PROCESSING	LANDFILL

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	pH	REDOX (mV)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	ACT SL CON-STAB	21800	16450	40000	1120	6.5	-110	N.D.	N.D.
TRIP 2	ACT SL CON-STAB	21650	17800	35200	N	5.9	-220	N.D.	N.D.
TRIP 3	ACT SL CON-STAB	20200	13850	67600	N	6.7	-390	N.D.	N.D.
TRIP 1	MESO AEROBIC DIG	26700	18000	51200	1940	6.5	-30	N.D.	N.D.
TRIP 2	MESO AEROBIC DIG	13530	10200	16000	N	6.6	-60	N.D.	N.D.
TRIP 3	MESO AEROBIC DIG	27100	17850	73000	N	7.0	-230	N.D.	N.D.
TRIP 1	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	80.3	40.9
TRIP 2	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	59.1	65.3
TRIP 3	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	44.8	40.2
	STORED DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	53.6	69.6

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	ACT SL CON-STAB	0	0	0	0	0	0	0	0
TRIP 2	ACT SL CON-STAB	0	0	0	0	0	0	909	909
TRIP 3	ACT SL CON-STAB	0	0	0	300	0	0	0	0
TRIP 1	MESO AEROBIC DIG	0	0	0	0	370	370	741	741
TRIP 2	MESO AEROBIC DIG	0	0	0	0	0	0	0	0
TRIP 3	MESO AEROBIC DIG	370	370	0	0	0	0	1111	1481
TRIP 1	DRYING BED	169	169	0	0	847	847	169	169
TRIP 2	DRYING BED	0	0	0	0	51	51	306	306
TRIP 3	DRYING BED	0	0	0	0	241	241	422	422
	STORED DRYING BED	75	75	0	0	0	0	376	526

APPENDIX D. (Continued)

THE STATE OF OHIO: PLANT 221

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGD	SEASONAL LOW FLOW IN MGD	SEASONAL HIGH FLOW IN MGD	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
4400000	190.00	120.00	240.00	3	SECONDARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
CATTLE PROCESSING [illegible] PROCESSING FOOD PROCESS MISC. CAN BODIES	LANDFILL

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (MG/L)	TOTAL VOLATILE SOLIDS (MG/L)	CHEMICAL OXYGEN DEMAND (MG/L)	TOTAL [illegible] (MG/L)	PH	REDOX (MV)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	SETTLED PRIMARY	75500	45300	113600	1260	6.0	-140	N.D.	N.D.
TRIP 2	SETTLED PRIMARY	29900	17600	36800	N	6.1	-270	N.D.	N.D.
TRIP 3	SETTLED PRIMARY	65100	39250	240000	N	6.5	-370	N.D.	N.D.
TRIP 1	MESO ANAEROBIC DIG	57600	32450	88000	1064	6.0	-150	N.D.	N.D.
TRIP 2	MESO ANAEROBIC DIG	59450	30700	60534	N	6.2	-125	N.D.	N.D.
TRIP 3	MESO ANAEROBIC DIG	64300	28750	120000	N	7.0	-390	N.D.	N.D.
TRIP 1	ZEN-PRO TREATMENT	91000	41050	111200	723	6.7	-100	N.D.	N.D.
TRIP 2	ZEN-PRO TREATMENT	163700	57900	137200	N	5.9	-60	N.D.	N.D.
TRIP 3	ZEN-PRO TREATMENT	160950	62350	229000	N	7.4	-220	N.D.	N.D.
TRIP 1	VACUUM FILTER	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	53.1	44.3
TRIP 2	VACUUM FILTER	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	61.5	54.6
TRIP 3	VACUUM FILTER	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	52.5	42.7

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS (EGGS)	TOTAL ASCARIS (EGGS)	VIABLE T. TRICHIURA (EGGS)	TOTAL T. TRICHIURA (EGGS)	VIABLE T. VULPIS (EGGS)	TOTAL T. VULPIS (EGGS)	VIABLE TOXOCARA (EGGS)	TOTAL TOXOCARA (EGGS)
TRIP 1	SETTLED PRIMARY	2348	3826	658	658	0	0	658	658
TRIP 2	SETTLED PRIMARY	35667	44000	3000	3000	0	0	667	667
TRIP 3	SETTLED PRIMARY	1692	2307	0	0	154	154	0	0
TRIP 1	MESO ANAEROBIC DIG	2386	4827	0	0	345	345	172	172
TRIP 2	MESO ANAEROBIC DIG	2381	2381	678	678	169	169	0	0
TRIP 3	MESO ANAEROBIC DIG	2656	3437	469	469	156	156	469	469
TRIP 1	ZEN-PRO TREATMENT	0	110	0	0	0	0	0	0
TRIP 2	ZEN-PRO TREATMENT	0	0	0	0	0	0	0	0
TRIP 3	ZEN-PRO TREATMENT	0	0	0	0	0	0	0	0
TRIP 1	VACUUM FILTER	0	0	0	0	0	0	0	0
TRIP 2	VACUUM FILTER	0	0	0	0	0	0	0	0
TRIP 3	VACUUM FILTER	0	0	0	0	0	0	0	0

APPENDIX D. (Continued)

THE STATE OF OHIO: PLANT 212

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
1400	N	N	N	27	PRIMARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
MACHINE SHOP	PUBLIC USE AT HOME

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	pH	REDOX (mVs)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	SETTLED PRIMARY	109100	47250	103200	1232	5.6	-232	N.D.	N.D.
TRIP 2	SETTLED PRIMARY	32550	18850	37600	N	5.5	-195	N.D.	N.D.
TRIP 3	SETTLED PRIMARY	14600	10330	50000	N	6.2	-330	N.D.	N.D.
TRIP 1	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	31.9	50.3
TRIP 2	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	23.2	9.8
TRIP 3	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	45.4	32.6

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	SETTLED PRIMARY	1101	1651	0	92	183	366	0	275
TRIP 2	SETTLED PRIMARY	0	0	0	0	1212	1212	3939	4242
TRIP 3	SETTLED PRIMARY	1765	1765	0	0	588	588	1765	1765
TRIP 1	DRYING BED	139	1458	0	69	417	486	208	416
TRIP 2	DRYING BED	43	86	0	0	87	87	43	130
TRIP 3	DRYING BED	183	305	0	0	61	61	427	732

APPENDIX D. (Continued)

THE STATE OF OHIO: PLANT 215

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
18000	7.50	.80	3.80	25	SECONDARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
MISC. PLASTIC PROD.	DRY FERT. CROPS

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	pH	REDOX (mVs)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	SETTLED PRIMARY	122400	24650	40000	1245	6.0	-100	N.D.	N.D.
TRIP 2	SETTLED PRIMARY	40000	34300	55467	N	5.7	-200	N.D.	N.D.
TRIP 3	SETTLED PRIMARY	N	N	110000	N	6.3	-240	N	N
TRIP 1	1 TO 2 MESO AN-DIG	42450	14200	35200	1064	6.9	-140	N.D.	N.D.
TRIP 2	1 TO 2 MESO AN DIG	100000	32100	38667	N	6.6	-170	N.D.	N.D.
TRIP 1	COVERED DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	61.0	30.7
TRIP 2	COVERED DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	30.5	N
TRIP 3	COVERED DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	9.9	33.7

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	SETTLED PRIMARY	0	0	0	0	0	0	164	164
TRIP 2	SETTLED PRIMARY	0	0	0	0	0	0	1224	1224
TRIP 3	SETTLED PRIMARY	667	1000	0	0	667	667	333	333
TRIP 1	1 TO 2 MESO AN DIG	0	0	233	233	2326	2326	1628	4884
TRIP 2	1 TO 2 MESO AN DIG	0	0	0	0	198	198	277	1188
TRIP 1	COVERED DRYING BED	0	83	0	0	598	598	684	940
TRIP 2	COVERED DRYING BED	0	0	0	0	239	239	144	192
TRIP 3	COVERED DRYING BED	0	0	0	0	0	220	0	0

APPENDIX D. (Continued)

THE STATE OF OHIO: PLANT 216

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
2100	.50	.14	.63	10	SECONDARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
NO INDUSTRY PRESENT	PUBLIC USE AT HOME LIQUID FERT. CROPS DRY FERT. CROPS LIQUID FERT PASTURE

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	pH	REDOX (mvs)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	ACT SL CON-STAB	26600	14600	52800	1680	6.1	-130	N.D.	N.D.
TRIP 2	ACT SL CON-STAB	27320	17850	22400	N	6.4	-220	N.D.	N.D.
TRIP 3	ACTIVATED SLUDGE	38150	16350	82000	N	6.9	-230	N.D.	N.D.
TRIP 1	MESO AEROBIC DIG	66850	27400	41600	448	6.1	-40	N.D.	N.D.
TRIP 2	MESO AEROBIC DIG	29900	13900	21600	N	6.7	-150	N.D.	N.D.
TRIP 3	MESO AEROBIC DIG	66700	26800	106000	N	7.2	-200	N.D.	N.D.

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	ACT SL CON-STAB	0	0	0	0	0	0	0	0
TRIP 2	ACT SL CON-STAB	0	0	0	0	0	0	357	357
TRIP 3	ACTIVATED SLUDGE	0	0	0	0	0	0	243	243
TRIP 1	MESO AEROBIC DIG	0	0	0	0	149	149	299	299
TRIP 2	MESO AEROBIC DIG	0	0	0	0	0	0	667	667
TRIP 3	MESO AEROBIC DIG	0	0	0	0	149	149	0	0

APPENDIX D. (Continued)

THE STATE OF OHIO: PLANT 217

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
N	N	N	N	15	SECONDARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
NO INDUSTRY PRESENT	PUBLIC USE AT HOME LANDFILL

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	pH	REDOX (mVs)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	SETTLED PRIMARY	33400	23700	91200	1616	5.3	-200	N.D.	N.D.
TRIP 2	SETTLED PRIMARY	37400	26450	57134	N	5.5	-210	N.D.	N.D.
TRIP 3	SETTLED PRIMARY	48300	33600	188000	N	5.4	-210	N.D.	N.D.
TRIP 1	IMHOFF DIGESTION	145850	69200	128400	1344	6.2	-135	N.D.	N.D.
TRIP 2	IMHOFF DIGESTION	105700	52050	13600	N	6.1	-115	N.D.	N.D.
TRIP 3	IMHOFF DIGESTION	N	N	N	N	6.5	-260	N	N
TRIP 1	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	71.1	33.9
TRIP 2	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	49.6	30.3
TRIP 3	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	38.4	38.8

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	SETTLED PRIMARY	0	0	0	0	0	0	303	303
TRIP 2	SETTLED PRIMARY	0	0	0	0	541	541	10541	10541
TRIP 3	SETTLED PRIMARY	0	0	0	0	208	208	417	417
TRIP 1	IMHOFF DIGESTION	0	46	0	137	1027	1164	342	958
TRIP 2	IMHOFF DIGESTION	0	0	0	0	189	189	943	1509
TRIP 2	IMHOFF DIGESTION	0	0	0	0	1351	1351	811	1622
TRIP 1	DRYING BED	0	115	0	0	690	690	115	575
TRIP 2	DRYING BED	0	0	0	132	396	662	0	0
TRIP 3	DRYING BED	0	0	0	0	162	162	0	226

APPENDIX D. (Continued)

THE STATE OF OHIO: PLANT 219

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
90000	13.50	7.00	40.00	17	PRIMARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
POULTRY PROCESSING	LANDFILL
INT. COMBUST. ENG.	SOLD TO DEALERS
WIRE PRODUCING	
STEEL FOUNDRIES	

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	PH	REDOX (mv)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	SETTLED PRIMARY	57100	34200	84800	1200	6.1	-125	N.D.	N.D.
TRIP 2	SETTLED PRIMARY	38300	20200	23000	N	6.4	-115	N.D.	N.D.
TRIP 3	SETTLED PRIMARY	39700	29000	47000	N	6.1	-160	N.D.	N.D.
TRIP 1	STORED PRIMARY	85850	45900	22400	2120	5.8	-115	N.D.	N.D.
TRIP 2	STORED PRIMARY	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	86.0	64.4
TRIP 3	STORED PRIMARY	157500	77950	107000	N	5.5	-220	N.D.	N.D.

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	SETTLED PRIMARY	175	175	0	175	175	175	1579	1579
TRIP 2	SETTLED PRIMARY	667	667	0	0	0	0	1333	1333
TRIP 3	SETTLED PRIMARY	250	250	0	0	500	500	3000	4250
TRIP 1	STORED PRIMARY	814	814	0	0	233	349	581	930
TRIP 2	STORED PRIMARY	0	0	0	0	238	238	1190	1190
TRIP 3	STORED PRIMARY	0	0	0	0	316	316	823	823

APPENDIX D. (Continued)

THE STATE OF NEW YORK: PLANT 301

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
300000	290.00	130.00	180.00	3	SECONDARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
NO INDUSTRY PRESENT	BARGED TO OCEAN

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	pH	REDOX (mVs)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	SETTLED PRIMARY	35100	27500	29600	2016	5.8	-180	N.D.	N.D.
TRIP 2	SETTLED PRIMARY	44900	32800	58800	1456	5.8	-200	N.D.	N.D.
TRIP 3	SETTLED PRIMARY	36000	27900	N	1040	N	N	N.D.	N.D.
TRIP 1	MESO ANAEROBIC DIG	34000	23350	47200	672	6.8	-200	N.D.	N.D.
TRIP 2	MESO ANAEROBIC DIG	24550	17100	27200	N	7.0	-220	N.D.	N.D.
TRIP 3	1 TO 2 MESO AN DIG	25200	15350	N	942	N	N	N.D.	N.D.
TRIP 1	STORED DIGESTED	37300	22150	80000	1288	6.8	-180	N.D.	N.D.
TRIP 2	STORED DIGESTED	34150	18700	27200	756	7.3	-250	N.D.	N.D.
TRIP 3	STORED DIGESTED	32500	18100	N	1214	N	N	N.D.	N.D.

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	SETTLED PRIMARY	2000	2000	2857	2857	1429	1429	2286	2286
TRIP 2	SETTLED PRIMARY	667	667	222	222	1111	1111	667	667
TRIP 3	SETTLED PRIMARY	3243	3513	1892	1892	811	811	1351	1351
TRIP 1	MESO ANAEROBIC DIG	857	1143	1429	1429	1429	1429	1143	1143
TRIP 2	MESO ANAEROBIC DIG	1852	1852	1111	1481	741	741	1852	2222
TRIP 3	1 TO 2 MESO AN DIG	6000	7200	0	0	1600	1600	2000	2400
TRIP 1	STORED DIGESTED	2973	3243	541	811	1892	1892	1622	1892
TRIP 2	STORED DIGESTED	588	588	294	2647	0	0	1471	2059
TRIP 3	STORED DIGESTED	2727	3030	2121	6060	909	909	2424	1333

APPENDIX D. (Continued)

THE STATE OF NEW YORK: PLANT 30C

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
450000	300.00	170.00	300.00	1	SECONDARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
MEAT RENDERING	BARGED TO OCEAN

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	pH	REDOX (mv)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	SETTLED PRIMARY	67700	50100	49600	1176	5.3	-150	N.D.	N.D.
TRIP 2	SETTLED PRIMARY	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	90.1	72.8
TRIP 3	SETTLED PRIMARY	23700	16900	N	1216	N	N	N.D.	N.D.
TRIP 1	1 TO 2 MESO AN DIG	60100	32950	96800	1128	7.3	-200	N.D.	N.D.
TRIP 2	1 TO 2 MESO AN DIG	62350	33950	87200	N	6.9	-220	N.D.	N.D.
TRIP 3	1 TO 2 MESO AN DIG	41200	22160	N	1010	N	N	N.D.	N.D.
TRIP 1	STORED DIGESTED	31350	18650	32000	1176	7.1	-210	N.D.	N.D.
TRIP 2	STORED DIGESTED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	78.0	60.1
TRIP 3	STORED DIGESTED	10530	5730	N	951	N	N	N.D.	N.D.

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	SETTLED PRIMARY	2647	3529	2794	3529	147	147	588	882
TRIP 2	SETTLED PRIMARY	1333	1500	500	833	333	333	667	667
TRIP 3	SETTLED PRIMARY	5833	6666	833	833	833	833	0	0
TRIP 1	1 TO 2 MESO AN DIG	4833	11500	1167	6000	500	833	667	2500
TRIP 2	1 TO 2 MESO AN DIG	7258	8710	1774	5645	645	968	1452	1613
TRIP 3	1 TO 2 MESO AN DIG	6098	7561	1951	10000	488	732	244	488
TRIP 1	STORED DIGESTED	2258	5806	2258	6452	323	1291	645	2258
TRIP 2	STORED DIGESTED	909	1667	606	1212	303	455	152	304
TRIP 3	STORED DIGESTED	4545	6363	0	7273	909	1818	909	909

APPENDIX D. (Continued)

THE STATE OF NEW YORK: PLANT 303

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
20000	8.00	.50	10.00	0	SECONDARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
	LANDFILL

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	pH	REDOX (mv)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	PRIMARY & ACTIVATED	29800	21450	50400	1896	5.8	-120	N.D.	N.D.
TRIP 2	PRIMARY & ACTIVATED	59050	47600	66400	1224	6.0	-190	N.D.	N.D.
TRIP 3	PRIMARY & ACTIVATED	38600	22500	0	1397	0	0	N.D.	N.D.
TRIP 2	LIMED PRIMARY	71200	54300	77600	991	5.6	-140	N.D.	N.D.
TRIP 1	VACUUM FILTER	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	82.2	53.4
TRIP 2	VACUUM FILTER	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	79.4	70.5
TRIP 3	VACUUM FILTER	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	87.5	47.6

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	PRIMARY & ACTIVATED	1379	1379	9655	10345	345	345	2069	2069
TRIP 2	PRIMARY & ACTIVATED	0	0	4068	4237	169	169	1186	1186
TRIP 3	PRIMARY & ACTIVATED	968	968	645	645	323	323	2258	2258
TRIP 2	LIMED PRIMARY	0	0	986	986	141	141	563	704
TRIP 1	VACUUM FILTER	185	185	185	370	185	185	0	926
TRIP 2	VACUUM FILTER	645	645	1452	1452	323	323	1290	1290
TRIP 3	VACUUM FILTER	263	1052	789	789	789	789	1053	1316

APPENDIX D. (Continued)

THE STATE OF NEW YORK: PLANT 304

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
1500	.35	.13	.90	3	SECONDARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
NO INDUSTRY PRESENT	PUBLIC USE AT HOME

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	pH	REDOX (mVs)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	ACT SL EXT-AER	12850	8600	44800	1217	6.8	-190	N.D.	N.D.
TRIP 2	ACT SL EXT-AER	21050	17450	28000	1008	6.4	-170	N.D.	N.D.
TRIP 3	ACT SL EXT-AER	18550	12450	N	1249	N	N	N.D.	N.D.
TRIP 3	MESO AEROBIC DIG	20700	13750	N	1214	N	N	N.D.	N.D.
TRIP 1	COVERED DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	86.9	54.2
TRIP 2	COVERED DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	46.3	66.9
TRIP 3	COVERED DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	71.9	38.2

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	ACT SL EXT-AER	0	0	0	769	0	0	0	0
TRIP 2	ACT SL EXT-AER	0	0	0	0	0	0	476	476
TRIP 3	ACT SL EXT-AER	0	0	0	0	2632	2632	6842	7368
TRIP 3	MESO AEROBIC DIG	0	0	476	476	952	952	6190	6666
TRIP 1	COVERED DRYING BED	0	0	0	256	513	769	0	256
TRIP 2	COVERED DRYING BED	0	0	0	0	62	62	62	62
TRIP 3	COVERED DRYING BED	0	0	0	0	471	471	4941	6117

APPENDIX D. (Continued)

THE STATE OF NEW YORK: PLANT 30a

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
40000	10.00	2.00	12.00	40	PRIMARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
FABRIC MILL COMMERCIAL PRINTING	PUBLIC USE AT HOME

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	pH	REDOX (mVs)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	SETTLED PRIMARY	11750	10100	76000	1400	5.6	-100	N.D.	N.D.
TRIP 2	SETTLED PRIMARY	13320	9650	10000	2386	5.6	-330	N.D.	N.D.
TRIP 3	SETTLED PRIMARY	19700	12150	N	1571	N	N	N.D.	N.D.
TRIP 1	MESO ANAEROBIC DIG	77050	40000	19200	1344	6.5	-130	N.D.	N.D.
TRIP 1	COVERED DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	79.6	45.9
TRIP 2	COVERED DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	11.7	44.0
TRIP 3	COVERED DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	7.7	47.9

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	SETTLED PRIMARY	0	0	0	0	0	0	375	375
TRIP 2	SETTLED PRIMARY	0	0	769	769	769	769	769	769
TRIP 3	SETTLED PRIMARY	0	0	0	0	0	0	1795	1795
TRIP 1	MESO ANAEROBIC DIG	0	0	0	0	675	675	250	1875
TRIP 1	COVERED DRYING BED	0	0	0	0	320	1140	0	320
TRIP 2	COVERED DRYING BED	0	0	0	0	0	75	0	113
TRIP 3	COVERED DRYING BED	0	0	0	0	100	397	0	0

APPENDIX D. (Continued)

THE STATE OF NEW YORK: PLANT 307

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
3300	.55	.23	.50	42	PRIMARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
FABRIC MILL TEXTILE DYING	PUBLIC USE AT HOME

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	pH	REDOX (mV)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	RAW INFLUENT	3100	2400	7200	1176	6.6	-120	N.D.	N.D.
TRIP 2	RAW INFLUENT	2300	2000	200	1019	7.0	-260	N.D.	N.D.
TRIP 3	RAW INFLUENT	2890	2010	A	1400	A	A	N.D.	N.D.
TRIP 1	IMHOFF DIGESTION	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	83.4	71.7
TRIP 3	IMHOFF DIGESTION	92200	71800	A	1332	A	A	N.D.	N.D.
TRIP 1	COVERED DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	72.4	62.3
TRIP 2	COVERED DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	68.5	70.7
TRIP 3	COVERED DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	41.0	69.5

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	RAW INFLUENT	0	0	0	0	0	0	6429	6429
TRIP 2	RAW INFLUENT	0	0	0	0	833	833	1667	1667
TRIP 3	RAW INFLUENT	0	5000	0	0	15000	15000	15000	15000
TRIP 1	IMHOFF DIGESTION	0	0	0	0	0	0	0	0
TRIP 3	IMHOFF DIGESTION	0	0	0	0	870	870	1304	1630
TRIP 1	COVERED DRYING BED	0	0	0	0	120	240	0	241
TRIP 2	COVERED DRYING BED	0	0	0	0	0	0	421	422
TRIP 3	COVERED DRYING BED	0	0	0	0	56	56	0	0

APPENDIX D. (Continued)

THE STATE OF NEW YORK: PLANT 308

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
3000	9.00	2.00	18.00	3	SECONDARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
NO INDUSTRY PRESENT	LANDFILL

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	pH	REDOX (mV)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	PRIMARY & ACTIVATED	29600	19500	60000	1238	5.8	-90	N.D.	N.D.
TRIP 2	PRIMARY & ACTIVATED	34100	26300	62000	2332	5.9	-190	N.D.	N.D.
TRIP 3	PRIMARY & ACTIVATED	39500	33800	N	1642	N	N	N.D.	N.D.
TRIP 1	1 TO 2 MESO AN DIG	89150	26000	44000	988	7.0	-120	N.D.	N.D.
TRIP 2	1 TO 2 MESO AN DIG	81000	42150	56400	816	6.9	-220	N.D.	N.D.
TRIP 3	1 TO 2 MESO AN DIG	52650	25600	N	1191	N	N	N.D.	N.D.
TRIP 1	VACUUM FILTER	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	80.6	45.3
TRIP 2	VACUUM FILTER	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	45.8	41.6
TRIP 3	VACUUM FILTER	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	80.5	42.1

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	PRIMARY & ACTIVATED	667	1000	0	333	333	333	1333	2000
TRIP 2	PRIMARY & ACTIVATED	500	500	0	0	0	0	882	882
TRIP 3	PRIMARY & ACTIVATED	0	1500	0	750	750	750	1000	1750
TRIP 1	1 TO 2 MESO AN DIG	337	786	0	225	112	561	112	449
TRIP 2	1 TO 2 MESO AN DIG	864	1728	247	494	370	370	247	370
TRIP 3	1 TO 2 MESO AN DIG	189	1698	0	1321	189	189	189	378
TRIP 1	VACUUM FILTER	345	862	0	517	172	689	0	2414
TRIP 2	VACUUM FILTER	0	0	0	0	0	0	0	0
TRIP 3	VACUUM FILTER	339	3051	0	678	508	508	169	3559

APPENDIX D. (Continued)

THE STATE OF NEW YORK: PLANT 310

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGD	SEASONAL LOW FLOW IN MGD	SEASONAL HIGH FLOW IN MGD	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
1500	.30	.12	1.50	33	PRIMARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
NO INDUSTRY PRESENT	PUBLIC USE AT HOME

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	pH	REDOX (mVs)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	SETTLED PRIMARY	18700	13000	24000	1336	5.5	-90	N.D.	N.D.
TRIP 3	SETTLED PRIMARY	14150	10450	*	1701	*	*	N.D.	N.D.
TRIP 1	MESO ANAEROBIC DIG	14450	10750	45600	1120	5.7	40	N.D.	N.D.
TRIP 3	MESO ANAEROBIC DIG	24050	15100	*	1149	*	*	N.D.	N.D.
TRIP 1	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	83.9	60.7
TRIP 2	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	82.9	73.0
TRIP 3	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	68.9	54.3

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	SETTLED PRIMARY	0	0	0	0	0	0	1404	1404
TRIP 3	SETTLED PRIMARY	0	0	0	0	0	0	2143	2143
TRIP 1	MESO ANAEROBIC DIG	0	0	0	0	0	0	0	4000
TRIP 3	MESO ANAEROBIC DIG	0	0	0	0	400	400	2800	3200
TRIP 1	DRYING BED	0	0	0	0	0	0	1458	1875
TRIP 2	DRYING BED	196	196	0	0	0	0	588	784
TRIP 3	DRYING BED	0	0	0	0	0	100	0	0

APPENDIX D. (Continued)

THE STATE OF NEW YORK: PLANT 112

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGD	SEASONAL LOW FLOW IN MGD	SEASONAL HIGH FLOW IN MGD	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
0	15.00	5.30	38.00	3	SECONDARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
COMMERCIAL PRINTING MISC. PLASTIC PROD.	LAWNS OF INDUSTRY

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	pH	REDOX (mV)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	SETTLED PRIMARY	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	93.1	76.1
TRIP 2	SETTLED PRIMARY	5800	4020	46000	1736	6.7	-220	N.D.	N.D.
TRIP 3	SETTLED PRIMARY	40500	31200	N	1624	N	N	N.D.	N.D.
TRIP 1	STORED PRIMARY	71300	46750	102400	2688	5.0	-90	N.D.	N.D.
TRIP 2	STORED PRIMARY	38300	23400	32800	1064	6.0	-190	N.D.	N.D.
TRIP 3	STORED PRIMARY	64400	42550	N	781	N	N	N.D.	N.D.
TRIP 1	COMPOST	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	26.2	11.4
TRIP 2	COMPOST	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	42.2	34.0
TRIP 3	COMPOST	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	32.0	27.0

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	SETTLED PRIMARY	0	0	0	0	0	0	0	0
TRIP 2	SETTLED PRIMARY	0	0	0	0	0	0	0	0
TRIP 3	SETTLED PRIMARY	0	0	732	732	0	0	244	488
TRIP 1	STORED PRIMARY	0	0	0	0	0	141	423	423
TRIP 2	STORED PRIMARY	0	333	333	333	333	333	667	667
TRIP 3	STORED PRIMARY	0	0	156	156	0	0	0	0
TRIP 1	COMPOST	0	0	0	0	0	0	0	0
TRIP 2	COMPOST	0	0	0	0	0	0	0	0
TRIP 3	COMPOST	0	0	0	0	0	0	0	0

APPENDIX D. (Continued)

THE STATE OF NEW YORK: PLANT 313

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
1100	.30	.07	.50	8	TERTIARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
COLLEGE OR UNIV.	LANDFILL

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	pH	REDOX (mVs)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	ACT SL CON-STAB	27900	17150	29600	784	7.0	-130	N.D.	N.D.
TRIP 2	ACT SL CON-STAB	25150	17790	19200	1009	6.9	-180	N.D.	N.D.
TRIP 1	MESO AEROBIC DIG	23450	14300	22400	1440	7.1	-40	N.D.	N.D.
TRIP 2	MESO AEROBIC DIG	24850	17350	24000	679	6.8	-230	N.D.	N.D.
TRIP 3	MESO AEROBIC DIG	16200	10267	N.D.	536	N.D.	N.D.	-663.2	-648.4
TRIP 1	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	26.2	11.4

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	ACT SL CON-STAB	0	0	0	0	0	0	2143	2143
TRIP 2	ACT SL CON-STAB	0	0	0	0	0	0	400	400
TRIP 1	MESO AEROBIC DIG	0	0	0	0	417	417	7083	7500
TRIP 2	MESO AEROBIC DIG	0	0	0	0	0	0	0	0
TRIP 3	MESO AEROBIC DIG	0	0	0	0	0	0	2197	2209
TRIP 1	DRYING BED	0	0	0	0	0	0	0	0

APPENDIX D. (Continued)

THE STATE OF NEW YORK: PLANT 214

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
50000	10.00	2.50	13.00	2	PRIMARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
MISC HEAT PROCESS	LANDFILL

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS IN mg/L	TOTAL VOLATILE SOLIDS IN mg/L	CHEMICAL OXYGEN DEMAND IN mg/L	TOTAL KJEDAHL NITROGEN IN mg/L	pH	REDOX IN mVOLTS	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	SETTLED PRIMARY	38150	24250	52800	1288	7.1	-105	N.D.	N.D.
TRIP 2	SETTLED PRIMARY	47050	27750	50000	1288	6.9	-230	N.D.	N.D.
TRIP 3	SETTLED PRIMARY	34450	23750	N	1721	N	N	N.D.	N.D.
TRIP 1	1 TO 2 MESO AN DIG	43250	20850	50400	616	7.4	-120	N.D.	N.D.
TRIP 2	1 TO 2 MESO AN DIG	47400	31950	52800	1008	7.1	-210	N.D.	N.D.
TRIP 3	1 TO 2 MESO AN DIG	70700	33150	N	928	N	N	N.D.	N.D.
TRIP 1	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	92.7	30.5
TRIP 3	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	46.5	41.7
TRIP 1	VACUUM FILTER	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	83.7	50.9
TRIP 2	VACUUM FILTER	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	79.1	49.9

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	SETTLED PRIMARY	312	747	6	0	0	0	406	623
TRIP 2	SETTLED PRIMARY	0	0	0	0	0	0	0	0
TRIP 3	SETTLED PRIMARY	236	236	0	0	0	0	236	236
TRIP 1	1 TO 2 MESO AN DIG	233	233	0	0	233	233	233	1376
TRIP 2	1 TO 2 MESO AN DIG	147	147	0	0	0	0	588	588
TRIP 3	1 TO 2 MESO AN DIG	0	282	0	282	423	564	423	1127
TRIP 1	DRYING BED	58	58	0	0	58	58	0	0
TRIP 3	DRYING BED	0	42	0	0	0	42	0	86
TRIP 1	VACUUM FILTER	208	1666	0	1875	0	0	0	0
TRIP 2	VACUUM FILTER	433	433	0	0	0	0	0	0

APPENDIX D. (Continued)

THE STATE OF NEW YORK: PLANT 318

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
400	.20	.03	1.00	39	TERTIARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
NO INDUSTRY PRESENT	DRY FERT. CROPS

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	pH	REDOX (mVs)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	RAW INFLUENT	1466	1100	8000	1792	6.7	-140	N.D.	N.D.
TRIP 2	RAW INFLUENT	233	163	200	1631	7.3	-90	N.D.	N.D.
TRIP 3	RAW INFLUENT	950	733	R	1000	R	R	N.D.	N.D.
TRIP 1	IMHOFF DIGESTION	183450	35050	84000	1064	6.5	-150	N.D.	N.D.
TRIP 2	IMHOFF DIGESTION	113600	47700	R	1904	6.4	-150	N.D.	N.D.
TRIP 3	IMHOFF DIGESTION	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	85.9	90.4
TRIP 1	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	46.1	29.2
TRIP 2	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	53.6	47.6
TRIP 3	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	44.3	29.7

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	RAW INFLUENT	0	0	0	0	0	0	7143	7143
TRIP 2	RAW INFLUENT	0	0	0	0	0	0	0	0
TRIP 3	RAW INFLUENT	0	0	0	0	0	0	0	0
TRIP 1	IMHOFF DIGESTION	0	0	0	0	0	54	163	1467
TRIP 2	IMHOFF DIGESTION	0	0	0	0	0	0	263	438
TRIP 3	IMHOFF DIGESTION	0	0	0	233	0	0	0	2093
TRIP 1	DRYING BED	0	0	0	0	0	0	185	370
TRIP 2	DRYING BED	0	0	0	0	72	72	72	228
TRIP 3	DRYING BED	0	0	60	60	0	120	120	479

APPENDIX D. (Continued)

THE STATE OF NEW YORK: PLANT 319

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
4700	.75	.42	.70	14	SECONDARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
METAL PLATING	LANDFILL

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	PH	REDOX (mvs)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	SETTLED PRIMARY	42400	31550	48000	952	6.1	-150	N.D.	N.D.
TRIP 2	SETTLED PRIMARY	23900	19000	32000	1624	6.1	-390	N.D.	N.D.
TRIP 3	SETTLED PRIMARY	24150	19250	R	1521	R	R	N.D.	N.D.
TRIP 1	MESO ANAEROBIC DIG	79250	48100	121600	1176	5.8	-110	N.D.	N.D.
TRIP 2	AN DIG SUPERNATANT	5650	4100	10000	472	5.3	-20	N.D.	N.D.
TRIP 3	AN DIG SUPERNATANT	900	730	R	730	R	R	N.D.	N.D.
TRIP 1	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	62.3	57.9
TRIP 2	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	50.6	57.4
TRIP 3	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	81.8	39.6

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	SETTLED PRIMARY	8140	9768	2791	3256	930	930	3093	3093
TRIP 2	SETTLED PRIMARY	0	0	1667	1667	0	0	3333	3333
TRIP 3	SETTLED PRIMARY	0	0	0	0	417	417	1667	1667
TRIP 1	MESO ANAEROBIC DIG	1266	2152	0	3797	127	760	0	1519
TRIP 2	AN DIG SUPERNATANT	0	0	0	0	0	0	0	0
TRIP 3	AN DIG SUPERNATANT	0	0	0	0	0	0	0	2000
TRIP 1	DRYING BED	0	0	88	176	88	442	88	265
TRIP 2	DRYING BED	0	0	68	338	68	271	0	68
TRIP 3	DRYING BED	364	1453	364	2364	182	546	0	2727

APPENDIX D. (Continued)

THE STATE OF WASHINGTON: PLANT 401

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
1500000	125.00	63.00	225.00	17	PRIMARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
CATTLE PROCESSING	TREE FARMS LAND RECLAMATION

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	pH	REDOX (mvs)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	SETTLED PRIMARY	47200	33300	76000	1844	5.1	-130	N.D.	N.D.
TRIP 2	SETTLED PRIMARY	54300.	41050	82000	1028	5.4	-210	N.D.	N.D.
TRIP 3	SETTLED PRIMARY	43350	33350	113000	1318	5.3	-200	N.D.	N.D.
TRIP 1	MESO ANAEROBIC DIG	27300	15150	32800	1424	7.1	-150	N.D.	N.D.
TRIP 2	1 TO 2 MESO AN DIG	32600	17700	30400	1008	7.1	-230	N.D.	N.D.
TRIP 3	1 TO 2 MESO AN DIG	22000	12150	78000	971	7.2	-210	N.D.	N.D.
TRIP 1	CENTRIFUGE	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	82.5	50.9
TRIP 2	CENTRIFUGE	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	82.2	48.4
TRIP 3	CENTRIFUGE	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	83.2	47.2

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	SETTLED PRIMARY	1489	1702	426	426	0	0	2553	2553
TRIP 2	SETTLED PRIMARY	1636	1636	364	364	0	0	909	909
TRIP 3	SETTLED PRIMARY	445	445	0	0	445	445	1860	1863
TRIP 1	MESO ANAEROBIC DIG	4444	8518	1481	3703	0	0	1111	2222
TRIP 2	1 TO 2 MESO AN DIG	6364	6364	0	0	0	0	606	606
TRIP 3	1 TO 2 MESO AN DIG	14348	20870	435	870	435	435	1739	2609
TRIP 1	CENTRIFUGE	4340	4529	755	755	0	0	755	944
TRIP 2	CENTRIFUGE	0	0	0	0	0	0	0	0
TRIP 3	CENTRIFUGE	9400	10400	1000	2200	400	400	800	1200

APPENDIX D. (Continued)

THE STATE OF WASHINGTON: PLANT 402

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
150000	27.00	12.00	50.00	27	PRIMARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
FISH PROCESSING	DRY FERT. CROPS
POULTRY PROCESSING	DRY FERT. PASTURES
HOG PROCESSING	

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	pH	REDOX (mVs)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	SETTLED PRIMARY	70000	50100	105600	N	5.7	-120	N.D.	N.D.
TRIP 2	SETTLED PRIMARY	17800	12500	29600	1728	5.6	-140	N.D.	N.D.
TRIP 3	SETTLED PRIMARY	33600	26500	138000	1416	5.5	-150	N.D.	N.D.
TRIP 1	1 TO 2 MESO AN DIG	52650	39250	61600	N	7.0	-142	N.D.	N.D.
TRIP 2	1 TO 2 MESO AN DIG	33150	28400	29600	796	6.7	-128	N.D.	N.D.
TRIP 3	1 TO 2 MESO AN DIG	52000	39330	128000	393	7.0	-200	N.D.	N.D.
TRIP 1	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	47.6	11.6
TRIP 2	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	33.8	7.5
TRIP 3	LAGOON	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	63.7	66.0

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	SETTLED PRIMARY	21887	34529	2264	3283	0	0	4131	4340
TRIP 2	SETTLED PRIMARY	2222	2778	1111	1111	0	0	2778	2778
TRIP 3	SETTLED PRIMARY	0	0	0	0	0	0	294	294
TRIP 1	1 TO 2 MESO AN DIG	30857	35428	1429	2858	571	571	2429	3000
TRIP 2	1 TO 2 MESO AN DIG	24286	26572	571	571	286	286	4571	6000
TRIP 3	1 TO 2 MESO AN DIG	5472	8114	377	1585	0	189	3330	3585
TRIP 1	DRYING BED	4013	9172	191	637	64	64	255	319
TRIP 2	DRYING BED	955	1508	50	50	0	0	101	252
TRIP 3	LAGOON	874	6738	194	1239	194	194	97	97

APPENDIX D. (Continued)

THE STATE OF WASHINGTON: PLANT 403

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
19000	4.30	2.10	8.50	19	PRIMARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
NO INDUSTRY PRESENT	LANDFILL

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	PH	REDOX (MV)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	SETTLED PRIMARY	14667	10100	34400	N	5.4	-146	N.D.	N.D.
TRIP 2	SETTLED PRIMARY	32300	23967	33200	1234	5.5	-160	N.D.	N.D.
TRIP 3	SETTLED PRIMARY	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	90.1	34.2
TRIP 1	MESO ANAEROBIC DIG	22950	12150	30400	1176	6.5	-182	N.D.	N.D.
TRIP 2	MESO ANAEROBIC DIG	27650	13300	34000	N	6.7	-200	N.D.	N.D.
TRIP 3	MESO ANAEROBIC DIG	20800	10400	53000	842	7.0	-250	N.D.	N.D.

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	SETTLED PRIMARY	667	667	0	0	0	0	2667	3334
TRIP 2	SETTLED PRIMARY	625	938	0	0	0	0	2813	2813
TRIP 3	SETTLED PRIMARY	667	667	333	333	0	0	5000	5000
TRIP 1	MESO ANAEROBIC DIG	0	0	0	0	455	455	2273	2728
TRIP 2	MESO ANAEROBIC DIG	1071	1071	0	0	357	357	714	1071
TRIP 3	MESO ANAEROBIC DIG	0	0	0	476	476	476	1429	1429

APPENDIX D. (Continued)

THE STATE OF WASHINGTON: PLANT 405

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
7000	7.30	.75	7.30	10	SECONDARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
CHEESE PROCESSING	LANDFILL
POULTRY PROCESSING	DRY FERT. CROPS
FRUITS AND VEGES	DRY FERT. PASTURES

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	pH	REDOX (mVs)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	SETTLED PRIMARY	68200	43700	104000	1680	5.4	-164	N.D.	N.D.
TRIP 2	SETTLED PRIMARY	37350	23000	44000	1000	5.7	-230	N.D.	N.D.
TRIP 3	SETTLED PRIMARY	41950	26590	124000	1694	5.9	-170	N.D.	N.D.
*TRIP 1	1 TO 2 MESO AN DIG	100450	49100	105600	1120	6.8	-190	N.D.	N.D.
TRIP 2	1 TO 2 MESO AN DIG	94900	46900	54000	786	6.8	-220	N.D.	N.D.
TRIP 3	1 TO 2 MESO AN DIG	131000	44000	170000	952	7.3	-210	N.D.	N.D.
TRIP 1	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	52.3	41.9
TRIP 2	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	76.4	47.0
TRIP 3	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	63.9	51.7

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	SETTLED PRIMARY	0	0	0	0	147	147	147	147
TRIP 2	SETTLED PRIMARY	0	0	0	0	0	0	1795	1795
TRIP 3	SETTLED PRIMARY	0	0	0	0	476	476	714	714
TRIP 1	1 TO 2 MESO AN DIG	198	198	0	198	0	99	297	594
TRIP 2	1 TO 2 MESO AN DIG	211	211	105	105	0	0	211	211
TRIP 3	1 TO 2 MESO AN DIG	229	305	76	76	76	76	76	229
TRIP 1	DRYING BED	0	0	0	0	0	0	70	70
TRIP 2	DRYING BED	0	0	0	0	286	286	143	286
TRIP 3	DRYING BED	0	0	0	208	0	0	0	208

APPENDIX D. (Continued)

THE STATE OF WASHINGTON: PLANT 407

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
7300	2.20	.40	4.00	7	SECONDARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
NO INDUSTRY PRESENT	STORED AT PLANT

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	pH	REDOX (mVs)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	ACTIVATED SLUDGE	14150	10350	23600	1064	5.9	-140	N.D.	N.D.
TRIP 2	ACTIVATED SLUDGE	15200	10920	15600	1274	6.5	-160	N.D.	N.D.
TRIP 3	ACTIVATED SLUDGE	8500	5800	23000	1274	6.5	-70	N.D.	N.D.
TRIP 1	MESO AEROBIC DIG	32330	22300	70400	1000	6.4	-115	N.D.	N.D.
TRIP 2	MESO AEROBIC DIG	27050	21100	27200	1200	6.1	-60	N.D.	N.D.
TRIP 3	MESO AEROBIC DIG	33400	22600	79000	R	5.6	-80	N.D.	N.D.
TRIP 1	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	71.6	62.8
TRIP 2	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	80.9	67.3
TRIP 3	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	73.9	38.3

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	ACTIVATED SLUDGE	47143	47143	0	0	0	0	7143	9286
TRIP 2	ACTIVATED SLUDGE	8000	8667	0	0	0	0	2667	3334
TRIP 3	ACTIVATED SLUDGE	12222	14444	0	0	0	0	2222	4444
TRIP 1	MESO AEROBIC DIG	27500	29063	0	0	313	313	1250	1875
TRIP 2	MESO AEROBIC DIG	14333	20333	333	333	333	333	5667	7334
TRIP 3	MESO AEROBIC DIG	18788	27273	606	606	606	606	2727	4545
TRIP 1	DRYING BED	471	471	118	118	706	1177	1294	2118
TRIP 2	DRYING BED	22121	39394	0	0	606	606	1515	2121
TRIP 3	DRYING BED	9487	11154	128	128	0	0	1154	1539

APPENDIX D. (Continued)

THE STATE OF WASHINGTON: PLANT 408

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGD	SEASONAL LOW FLOW IN MGD	SEASONAL HIGH FLOW IN MGD	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
4600	2.50	.50	4.00	2	PRIMARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
CATTLE PROCESSING HOG PROCESSING	LAGOONS

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	PH	REDOX (mvs)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	SETTLED PRIMARY	30150	18050	95200	616	4.8	-120	N.D.	N.D.
TRIP 2	SETTLED PRIMARY	67000	27400	61200	1368	5.6	-100	N.D.	N.D.
TRIP 3	LINED PRIMARY	45450	23350	103000	1313	5.8	-220	N.D.	N.D.
TRIP 1	LINED LAGOON	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	71.0	26.4
TRIP 2	LINED LAGOON	163250	58000	#	326	5.6	-190	N.D.	N.D.
TRIP 3	LINED LAGOON	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	52.9	51.9

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.CANIS EGGS	TOTAL T.CANIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	SETTLED PRIMARY	2333	2333	2000	2667	0	0	1333	1333
TRIP 2	SETTLED PRIMARY	5147	7794	1224	1224	0	0	735	735
TRIP 3	LINED PRIMARY	1957	1957	217	217	0	0	0	0
TRIP 1	LINED LAGOON	1149	1149	115	115	0	0	0	0
TRIP 2	LINED LAGOON	1942	2427	485	485	0	0	0	0
TRIP 3	LINED LAGOON	8387	9677	1452	1452	0	0	0	0

APPENDIX D. (Continued)

THE STATE OF WASHINGTON: PLANT 409

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGD	SEASONAL LOW FLOW IN MGD	SEASONAL HIGH FLOW IN MGD	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
34000	6.50	2.30	6.30	8	SECONDARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
FOOD PROCESS MISC.	LANDFILL PUBLIC USE AT HOME GOLF COURSES

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	pH	REDOX (mV)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	SETTLED PRIMARY	38850	27900	95200	2741	5.9	-200	N.D.	N.D.
TRIP 2	SETTLED PRIMARY	32450	27900	35600	1280	5.9	-210	N.D.	N.D.
TRIP 3	SETTLED PRIMARY	61550	41150	172000	1299	5.6	-210	N.D.	N.D.
TRIP 1.	1 TO 2 WEEKS AN DIG	66900	34100	144000	2184	6.9	-190	N.D.	N.D.
TRIP 2	1 TO 2 WEEKS AN DIG	74700	46600	11400	658	7.0	-160	N.D.	N.D.
TRIP 3	1 TO 2 WEEKS AN DIG	63300	35100	148000	893	6.9	-230	N.D.	N.D.
TRIP 1	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	43.5	45.4
TRIP 2	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	52.5	42.3
TRIP 3	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	7.6	49.5

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	SETTLED PRIMARY	5128	7179	0	0	769	769	513	513
TRIP 2	SETTLED PRIMARY	15758	17576	0	0	0	0	303	303
TRIP 3	SETTLED PRIMARY	323	323	0	0	161	161	323	323
TRIP 1	1 TO 2 WEEKS AN DIG	0	0	0	0	0	0	0	0
TRIP 2	1 TO 2 WEEKS AN DIG	16667	21334	267	534	267	267	0	133
TRIP 3	1 TO 2 WEEKS AN DIG	9524	11111	317	952	317	317	0	635
TRIP 1	DRYING BED	0	0	0	0	0	0	0	0
TRIP 2	DRYING BED	0	0	0	0	0	140	0	0
TRIP 3	DRYING BED	0	0	0	0	0	0	0	0

APPENDIX D. (Continued)

THE STATE OF WASHINGTON: PLANT 410

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
300000	77.00	30.00	125.00	2	SECONDARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
CATTLE PROCESSING HOG PROCESSING METAL PLATING	LANDFILL

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	pH	REDOX (mVs)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	SETTLED PRIMARY	40900	37900	200000	1560	4.7	-100	N.D.	N.D.
TRIP 2	SETTLED PRIMARY	23130	8250	89600	1512	4.6	-110	N.D.	N.D.
TRIP 3	SETTLED PRIMARY	142450	57300	286000	1401	5.3	-160	N.D.	N.D.
TRIP 1	MESO ANAEROBIC DIG-	30330	17400	34400	784	7.0	-140	N.D.	N.D.
TRIP 2	MESO ANAEROBIC DIG	30450	13050	21600	1008	7.0	-280	N.D.	N.D.
TRIP 3	MESO ANAEROBIC DIG	42500	17000	54000	737	7.0	-180	N.D.	N.D.
TRIP 2	FERRIC & LIME DIG	35400	15200	18400	1230	7.0	-200	N.D.	N.D.
TRIP 1	VACUUM FILTER	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	85.3	30.0
TRIP 2	VACUUM FILTER	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	84.7	39.5
TRIP 3	VACUUM FILTER	N	N	N	N	N	N	N	N

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	SETTLED PRIMARY	145	145	0	0	0	0	290	290
TRIP 2	SETTLED PRIMARY	1739	1739	435	435	0	0	2174	2174
TRIP 3	SETTLED PRIMARY	64	64	0	0	0	0	64	64
TRIP 1	MESO ANAEROBIC DIG	2000	2000	333	333	0	0	333	333
TRIP 2	MESO ANAEROBIC DIG	1290	1290	323	323	0	0	645	968
TRIP 3	MESO ANAEROBIC DIG	930	930	0	0	0	0	233	233
TRIP 2	FERRIC & LIME DIG	2371	2371	0	0	236	236	236	236
TRIP 1	VACUUM FILTER	455	455	0	0	0	0	0	0
TRIP 2	VACUUM FILTER	1087	1087	0	0	0	0	435	435
TRIP 3	VACUUM FILTER	0	0	0	0	0	0	0	0

APPENDIX D. (Continued)

THE STATE OF WASHINGTON: PLANT 411

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
14000	4.00	.85	4.00	25	SECONDARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
MILK PROCESSING CATTLE PROCESSING HOG PROCESSING	LANDFILL

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	pH	REDOX (mVs)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	SETTLED PRIMARY	50400	37100	142400	1540	5.4	-225	N.D.	N.D.
TRIP 2	SETTLED PRIMARY	16100	12350	21600	1336	6.6	-230	N.D.	N.D.
TRIP 3	SETTLED PRIMARY	23200	11400	58000	M	5.7	-290	N.D.	N.D.
TRIP 1	1 TO 2 TPH AN DIG	24000	11600	76000	304	7.2	-130	N.D.	N.D.
TRIP 2	1 TO 2 TPH AN DIG	38555	30100	32000	805	7.2	-210	N.D.	N.D.

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	SETTLED PRIMARY	0	0	0	0	0	0	200	200
TRIP 2	SETTLED PRIMARY	0	625	0	0	0	0	625	625
TRIP 3	SETTLED PRIMARY	0	0	400	400	0	0	0	0
TRIP 1	1 TO 2 TPH AN DIG	0	0	0	0	0	0	0	0
TRIP 2	1 TO 2 TPH AN DIG	0	0	0	256	0	0	256	256

APPENDIX D. (Continued)

THE STATE OF WASHINGTON: PLANT #13

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGD	SEASONAL LOW FLOW IN MGD	SEASONAL HIGH FLOW IN MGD	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
14000	15.00	1.50	5.50	5	SECONDARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
NO INDUSTRY PRESENT	LIQUID FERT PASTURE

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	pH	REDOX (mV)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	ACT SL EXT-AER	16500	12150	82400	0	6.5	-135	N.D.	N.D.
TRIP 2	ACT SL EXT-AER	26150	18550	21600	1293	6.5	-140	N.D.	N.D.
TRIP 3	ACTIVATED SLUDGE	14400	7700	36000	831	6.2	-210	N.D.	N.D.
TRIP 1	MESO ANAEROBIC DIG	26500	16300	82400	372	6.8	-175	N.D.	N.D.
TRIP 2	MESO ANAEROBIC DIG	17300	12300	17500	1261	7.0	-200	N.D.	N.D.
TRIP 3	MESO ANAEROBIC DIG	8250	4850	27000	952	6.8	-150	N.D.	N.D.
TRIP 2	1 TO 2 MESO AN DIG	21100	12200	18000	930	7.0	-200	N.D.	N.D.
TRIP 3	1 TO 2 MESO AN DIG	11400	5250	23000	1100	6.7	-160	N.D.	N.D.

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	ACT SL EXT-AER	1765	2353	0	0	0	0	588	1176
TRIP 2	ACT SL EXT-AER	385	385	0	0	0	0	769	769
TRIP 3	ACTIVATED SLUDGE	714	1428	0	0	0	0	2143	2857
TRIP 1	MESO ANAEROBIC DIG	4074	5185	0	370	0	0	2222	2222
TRIP 2	MESO ANAEROBIC DIG	1579	2105	0	0	0	0	1053	1053
TRIP 3	MESO ANAEROBIC DIG	1250	1250	0	0	0	0	0	0
TRIP 2	1 TO 2 MESO AN DIG	1429	2858	476	476	1905	1905	476	1428
TRIP 3	1 TO 2 MESO AN DIG	0	0	0	0	0	0	0	0

APPENDIX D. (Continued)

THE STATE OF WASHINGTON: PLANT 414

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
15000	1.50	.40	1.10	9	SECONDARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
NO INDUSTRY PRESENT	LIQUID FERT PASTURE PUBLIC USE AT HOME

CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (mg/L)	TOTAL VOLATILE SOLIDS (mg/L)	CHEMICAL OXYGEN DEMAND (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	pH	REDOX (mVs)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	SETTLED PRIMARY	21300	17100	72000	616	5.6	-170	N.D.	N.D.
TRIP 2	SETTLED PRIMARY	33650	23650	52800	1679	6.0	-200	N.D.	N.D.
TRIP 3	SETTLED PRIMARY	31600	23750	99000	1423	5.4	-200	N.D.	N.D.
TRIP 1	1 TO 2 MESO AN DIG	14250	9630	73600	1120	6.6	-145	N.D.	N.D.
TRIP 2	1 TO 2 MESO AN DIG	16800	11450	14800	1008	6.9	-230	N.D.	N.D.
TRIP 3	MESO ANAEROBIC DIG	24350	19750	64600	723	6.6	-250	N.D.	N.D.
TRIP 1	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	78.7	58.6
TRIP 2	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	90.0	62.3
TRIP 3	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	16.3	48.9

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE ASCARIS EGGS	TOTAL ASCARIS EGGS	VIABLE T.TRICH EGGS	TOTAL T.TRICH EGGS	VIABLE T.VULPIS EGGS	TOTAL T.VULPIS EGGS	VIABLE TOXOCARA EGGS	TOTAL TOXOCARA EGGS
TRIP 1	SETTLED PRIMARY	0	0	952	952	0	0	0	0
TRIP 2	SETTLED PRIMARY	588	588	0	0	0	0	0	0
TRIP 3	SETTLED PRIMARY	0	0	0	313	0	0	1563	1563
TRIP 1	1 TO 2 MESO AN DIG	0	0	0	0	714	714	714	714
TRIP 2	1 TO 2 MESO AN DIG	4706	4706	588	588	0	0	1176	1176
TRIP 3	MESO ANAEROBIC DIG	0	0	0	0	0	0	0	0
TRIP 1	DRYING BED	0	0	0	0	0	0	0	0
TRIP 2	DRYING BED	4000	4333	0	0	0	0	667	1000
TRIP 3	DRYING BED	40	40	0	40	0	0	0	0

APPENDIX D. (Continued)

THE STATE OF WASHINGTON: PLANT 413

TREATMENT PLANT CHARACTERISTICS

POPULATION SERVED	DESIGN FLOW IN MGDS	SEASONAL LOW FLOW IN MGDS	SEASONAL HIGH FLOW IN MGDS	AGE OF SYSTEM IN YEARS	MAXIMUM EFFLUENT TREATMENT
1500	.30	.10	1.50	6	SECONDARY TREATMENT

INDUSTRY SERVED	TYPE SLUDGE DISPOSAL
CANNED FRTS & VEGS	HIGHWAY MEDIANS PARKS

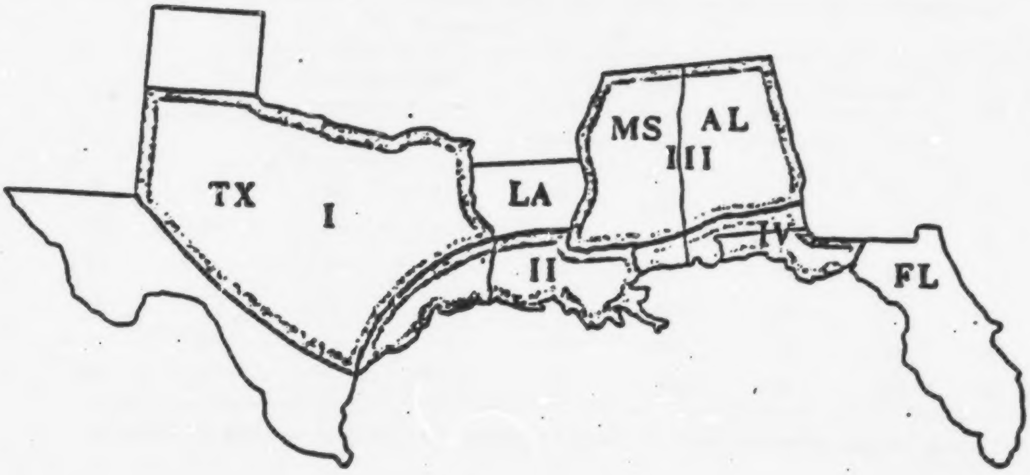
CHEMICAL CHARACTERISTICS OF SLUDGE SAMPLES

TRIP	SITE OF SLUDGE COLLECTION	TOTAL SUSPENDED SOLIDS (MG/L)	TOTAL VOLATILE SOLIDS (MG/L)	CHEMICAL OXYGEN DEMAND (MG/L)	TOTAL KJELDAHL NITROGEN (MG/L)	PH	REDOX (MVOL)	PERCENT MOISTURE CONTENT	PERCENT VOLATILE SOLIDS
TRIP 1	ACT SL EXT-AER	20750	14750	79200	784	5.7	-110	N.D.	N.D.
TRIP 2	ACT SL EXT-AER	17600	16100	23600	1064	6.2	-200	N.D.	N.D.
TRIP 3	ACT SL EXT-AER	11650	9600	48000	N	5.8	-200	N.D.	N.D.
TRIP 1	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	50.0	27.6
TRIP 2	DRYING BED	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	54.4	45.8

PARASITE EGGS PER KILOGRAM DRY WEIGHT OF SLUDGE

TRIP	SITE OF SLUDGE COLLECTION	VIABLE *ASCARIS* EGGS	TOTAL *ASCARIS* EGGS	VIABLE *T.TRICH* EGGS	TOTAL *T.TRICH* EGGS	VIABLE *T.VULPIS* EGGS	TOTAL *T.VULPIS* EGGS	VIABLE *TOXOCARA* EGGS	TOTAL *TOXOCARA* EGGS
TRIP 1	ACT SL EXT-AER	0	0	0	0	0	0	476	476
TRIP 2	ACT SL EXT-AER	0	0	0	0	0	0	1000	1000
TRIP 3	ACT SL EXT-AER	0	0	833	833	8333	8333	833	833
TRIP 1	DRYING BED	0	0	0	0	0	0	0	0
TRIP 2	DRYING BED	0	0	0	0	0	0	0	0

APPENDIX E. GEOGRAPHIC REGIONS IN THE SOUTH IN WHICH MUNICIPAL WASTE TREATMENT PLANTS WERE STUDIED



APPENDIX F. EFFECTS OF LABORATORY STUDIES ON THE EFFECTS OF CONTINUOUS AEROBIC DIGESTION ON *ASCARIS* EGGS

TABLE F1. INFLUENCE OF CONTINUOUS AEROBIC DIGESTION PROCESS AT 25°C WITH A 10-DAY DETENTION TIME ON *ASCARIS* EGGS

Day	No. of eggs recovered[1]							
	Sample no. 1		Sample no. 2		Sample no. 3		Average no. viable	S.D.
	Viable	Nonviable	Viable	Nonviable	Viable	Nonviable		
0	477	46	452	58	496	24	475	22
2	390	46	503	57	---	---	447	80
4	349	29	236	17	341	24	309	63
6	226	30	208	25	199	26	211	14
8	165	22	186	30	254	34	202	47
10	152	30	154	24	126	19	144	16

[1] Number of eggs recovered from 50 ml samples. *Ascaris* eggs added at beginning of incubation period.

TABLE F2. INFLUENCE OF CONTINUOUS AEROBIC DIGESTION PROCESS AT 25°C WITH A 20-DAY DETENTION TIME ON *ASCARIS* EGGS

Day	No. of eggs recovered[1]							
	Sample no. 1		Sample no. 2		Sample no. 3		Average no. viable	S.D.
	Viable	Nonviable	Viable	Nonviable	Viable	Nonviable		
0	426	98	452	133	550	91	476	65
4	331	64	345	46	445	83	374	62
7	327	71	177	33	---	---	252	106
11	238	49	234	38	152	23	208	49
14	192	51	170	47	---	---	181	16
21	158	23	167	25	148	36	158	10

[1] Number of eggs recovered from 50 ml samples. *Ascaris* eggs added at beginning of incubation period.

APPENDIX F. EFFECTS OF LABORATORY STUDIES ON THE EFFECTS OF CONTINUOUS AEROBIC DIGESTION ON ASCARIS

TABLE F3. INFLUENCE OF CONTINUOUS AEROBIC DIGESTION PROCESS AT 25°C WITH A 30-DAY DETENTION TIME ON ASCARIS

Day	No. of eggs recovered[1]							
	Sample no. 1		Sample no. 2		Sample no. 3		Average no. viable	S.D.
	Viable	Nonviable	Viable	Nonviable	Viable	Nonviable		
0	532	79	653	65	484	48	556	87
4	265	35	367	31	411	38	348	75
7	439	52	598	65	517	35	518	80
11	434	69	428	13	473	70	445	24
14	236	85	270	58	---	---	253	24
18	334	41	357	16	337	14	343	12
21	307	15	319	29	325	18	317	9
28	239	5	257	6	258	16	251	11
31	228	13	185	18	190	4	201	24

[1] Number of eggs recovered from 50 ml samples. *Ascaris* eggs added at beginning of incubation period.

TABLE F4. INFLUENCE OF CONTINUOUS AEROBIC DIGESTION PROCESS AT 35°C WITH A 10-DAY DETENTION TIME ON *ASCARIS* EGGS

Day	No. of eggs recovered[1]							
	Sample no. 1		Sample no. 2		Sample no. 3		Average no. viable	S.D.
	Viable	Nonviable	Viable	Nonviable	Viable	Nonviable		
0	496	33	583	30	568	17	549	47
2	454	37	326	14	406	16	395	65
4	225	20	269	27	242	26	245	22
6	127	60	168	77	171	91	155	25
8	76	89	122	54	92	51	97	23
10	167	63	133	38	79	26	126	44

[1] Number of eggs recovered from 50 ml samples. *Ascaris* eggs added at beginning of incubation period.

APPENDIX F. (Continued)

F5. INFLUENCE OF CONTINUOUS AEROBIC DIGESTION PROCESS AT 35°C WITH A 20-DAY DETENTION TIME ON *ASCARIS* EGGS

Day	No. of eggs recovered[1]							
	Sample no. 1		Sample no. 2		Sample no. 3		Average no. viable	S.D.
	Viable	Nonviable	Viable	Nonviable	Viable	Nonviable		
0	670	89	676	94	—	—	673	4
4	468	162	496	123	476	131	480	14
7	45	293	65	277	59	259	56	10
11	34	281	47	205	23	219	35	12
14	8	97	34	235	4	59	15	16
21	22	118	17	160	26	233	22	5

[1] Number of eggs recovered from 50 ml samples. *Ascaris* eggs added at beginning of incubation period.